# A NEW ROADWAY BLOCK PAVEMENT CONSTRUCTED BY CEMENT-ASPHALT EMULSION GROUT

TAKUO TAMAKI,TECHNOLOGY DEPARTMENT,TAISEI ROTEC CO.,LTD.
3-13-1 Kyobashi,Chuo,Tokyo 104-1311 Japan
TEL +81-3-3567-9648 FAX +81-3-3561-5342
E-MaiL takuo_tamaki@taiseirotec.co.jp
YOSHITAKA ECHIKAWA, TECHNICAL RESERCH LAB.,TAISEI ROTEC CO.,LTD.
TAKAHIRO YAMAMOTO,TECHNICAL RESERCH LAB.,NICHIREKI CO.,LTD.

## ABSTRACT

Instances have been increasing in which a block pavement that gives consideration to the landscape is adopted not only for sidewalks but also for roadways. However, the existing method of block pavement construction is not suited for such roadways on which heavy vehicles run. Therefore, we developed a CAE grout injection method suited for roadways as well. This method forms a uniform adhesion layer that is high in shock absorption, using a cement-asphalt emulsion grouting material (CAE grout) excellent in fluidity for the adhesion layer that supports blocks, in order to improve the serviceability and durability of block pavements. With this method, more than 70 block pavements suited for roadways have been constructed in the past (one to five years have passed after they were put into service). In order to investigate the results of these pavements, we conducted a follow-up survey by FWD (Falling Weight Deflectometer), etc., of their performance after having been put into service. As a result, the pavements were found to be in good condition with no broken block, notwithstanding the harsh service conditions. Though even the longest of the service periods of the pavements does not exceed about five years yet, it was found that such spots which would suffer damage within one year in the case of the existing method remain in good condition. Therefore, this method can be said to be epoch-making in that block pavements can be freely adopted for roadways as well as for sidewalks.

## 1. INTRODUCTION

Recently in Japan, block pavements have been finding increasing applications as pavements that give consideration to the landscape and allow people, particularly pedestrians, to feel comfortable and at ease. However, not a few instances of fracture have occurred in the block pavements constructed in such places where the traffic volume of heavy vehicles is high, e.g., roadways in urban areas, and parking lots in scenic spots.
The solution developed to eliminate these drawbacks is the CAE grout injection method (called "injection method").The injection method replaces the existing bonding layer (cement mortar layer) with an asphalt-based bonding layer high in shock absorption and great in adhesion (called "CAE grout layer") that uses an asphalt-based filler that is excellent in fluidity (cement asphalt emulsion grout; CAE grout).
This paper introduces the history of the development of the injection method, material properties of CAE grout, investigation results of in-situ serviceability and durability obtained through an actual application of the injection method.

## 2. HISTORY OF DEVELOPMENT OF INJECTION METHOD

### 2.1 CAUSE OF FRACTURE WITH THE CONVENTIONAL METHOD

Figure 1 illustrates the structure of a block pavement by the conventional method. As shown in the figure, the pavement is constructed by placing blocks on a base concrete

pavement with a cement mortar (dry mixed) layer provided in-between to support and stabilize them.

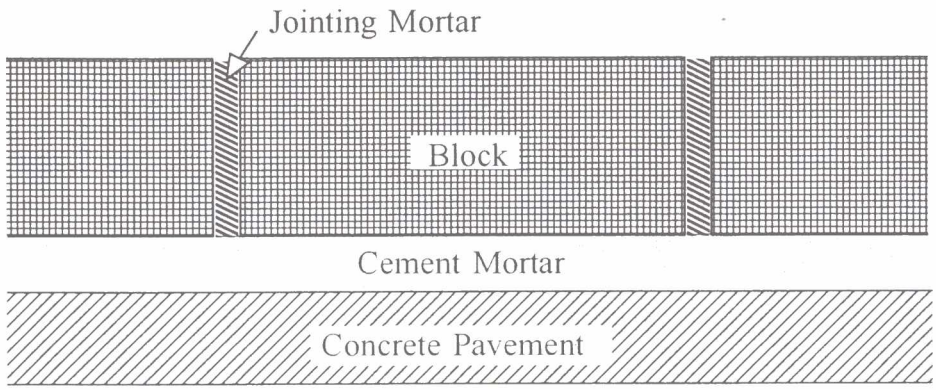


**Figure 1 Pavement Structure by Conventional Method**

As a result of investigating the damage condition with this construction method, the following could be confirmed:

① The block pavement is damaged even where no damage is observed on the base concrete pavement.

② Where damage has progressed to such a degree as to cause faulting in the block pavement, a spurt of cement mortar or sand is observed on the block pavement surface.

③ The thicker cement mortar layer results in more pronounced fracture.

Therefore, the cause of fracture of the block pavement was considered attributable to the cement mortar layer. Considering it necessary to investigate the properties of the cement mortar layer, cut specimens were taken to measure its compressive strength. As a result, the following could be confirmed in terms of the relation between compressive strength and density (see Figure 2):

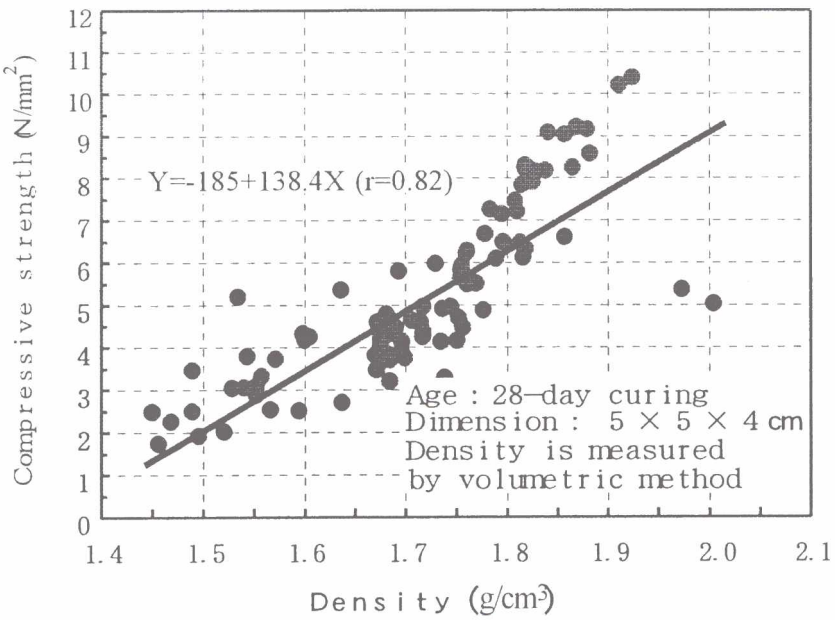


**Figure 2 Relation between Compressive Strength and Density of Cement Mortar Layer**

① Voids ratio of cut specimens: Scatter is large, and voids ratio is high (9-29%)
② Compressive strength of cut specimens: Differs about 10-fold depending on density (1.5-10. 5N/mm $^2$) .

Based on the above-mentioned test and investigation results, the cause of fracture of the block pavement was considered due to the fact that the cement mortar layer required to support and stabilize the blocks was nonuniform in density and strength.

In Japan, attempts have been made to improve adhesion by using resins in place of cement mortar in order to remove the drawbacks of the conventional method. However, from the results of investigating the fracture of the block pavement and the relation between compressive strength and density, it was assumed that in the case of block pavements it would be basically difficult to construct a uniform bonding layer as far as a compacting material is used.

### 2.2 DEVELOPMENT OF THE INJECTION METHOD

Taking into consideration the cause of fracture with the conventional method, the objectives of developing the injection method were established as follows:
① Using a cold injectable material in place of a compacting material for the bonding layer.
② Making the bonding layer flexible by use of an asphalt-based material.
③ Enabling early opening to traffic for repairs.

A CAE grout excellent in safety and fluidity was selected to attain these development objectives.

## 3. DEVELOPMENT OF CAE GROUT

### 3.1 OBJECTIVES OF DEVELOPING CAE GROUT

The development objectives listed below were established for the CAE grout for use with the bonding layer that supports blocks.
① Being a filler capable of constructing a uniform and highly fluidic bonding layer.
An evaluation test was made using a model, and an optimum consistency for CAE grout was determined from the relation between the amount of water added and the grouting distance. It was found that the optimum consistency for grouting crushed stone in sizes of 13 to 5 mm is such that the grouting distance becomes about 200 mm in the horizontal direction. The then value of P-funnel flow time of the CAE grout, 11± 2 seconds, was determined as the aimed consistency.
② Being high in shock absorption and durable under repeated loads.The elastic modulus of flexure of the CAE grout layer formed by grouting crushed stone with an asphalt emulsion-containing grout must be less than 20,000 N/mm$^2$ .
③ Being capable of developing sufficient strength for early opening to traffic.The grout mush develop a necessary strength of 0.5 N/mm$^2$ or more for opening to traffic after three hours cure.

### 3.2 MATERIALS

① Asphalt emulsion
The asphalt emulsion used in this development was a nonionic type that is suitable for mixing with cement.It was an apparently brown material in liquid phase at ordinary temperature with an evaporation residue of 58.7 % and a penetration of 87, in which1-10 $\mu$ m asphalt and polymer particles are dispersed.
② Rapid-setting cement

The cement used was a rapid-setting type that maintains workability for 30 minutes or more and begins to set within one hour.

③ Others

The amount of water added was adjusted so that the grout consistency was in the aimed range of 11±2 seconds in P-funnel flow time. In addition, silica sand, setting regulator,water, etc., were added as required.

### 3.3 DEVELOPMENT RESULTS

The main factor that determines conflicting properties of strength and flexibility is the ratio of asphalt emulsion to cement, i.e., emulsion-cement ratio (E/C). With this factor as the basis, the E/C ratio at which the aimed strength and flexibility can be balanced was calculated to determine the mix proportion for CAE grout.

(1) Determination of emulsion mixing ratio

The strength of the CAE grout three hours after mixing up was measured for different E/C ratios. As a result, the relation between E/C and strength as shown in Figure 3 was obtained. It was found that the aimed strength at 20 ℃ could be attained by setting the E/C ratio at 0.8 or less. On the other hand, it was necessary to set the E/C ratio at 0.5 or less in order to attain the aimed strength at 5 ℃. Based on this result, the E/C ratio was determined as 0.5.

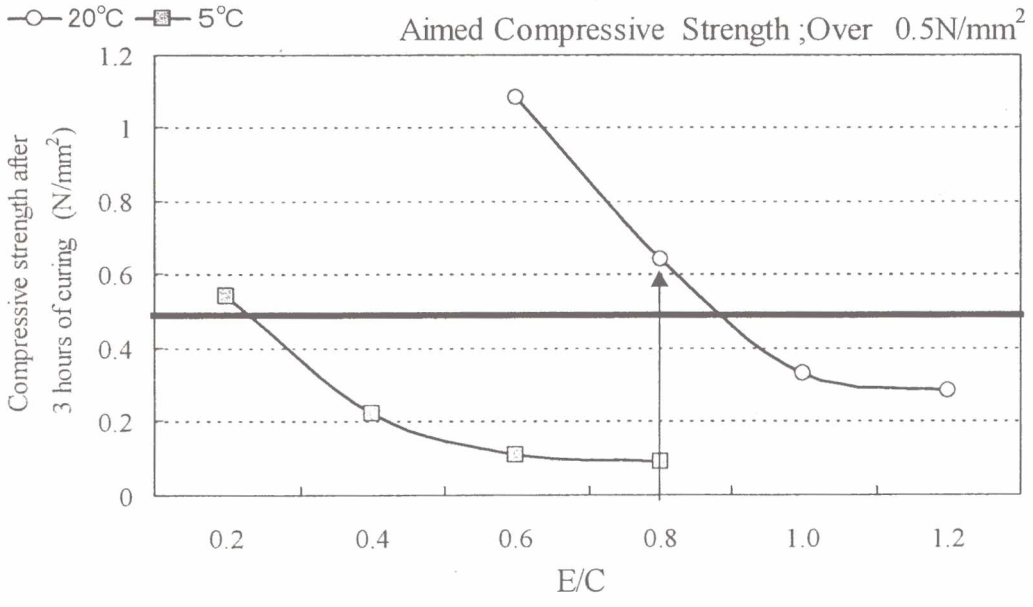


**Figure 3 Relation between E/C and Strength**

(2) Flexibility confirmation test

Bending test specimens 4 cm by 4 cm by 16 cm were prepared with the selected mixing ratio (E/C = 0.5) and cured for 7 days at 20 ℃. The specimens were measured for elastic modulus of flexure at a loading speed of 1 mm/min. The obtained results are given in Figure 4.

It was confirmed that the hardened CAE grout and the layerformed by filling the crushed stone layer with the grout(CAE grout layer) are better in flexibility than cement concrete (E/C = 0), and that their elastic modulus of flexure is less than 20.000 N/mm$^2$ , the value aimed at in this method.

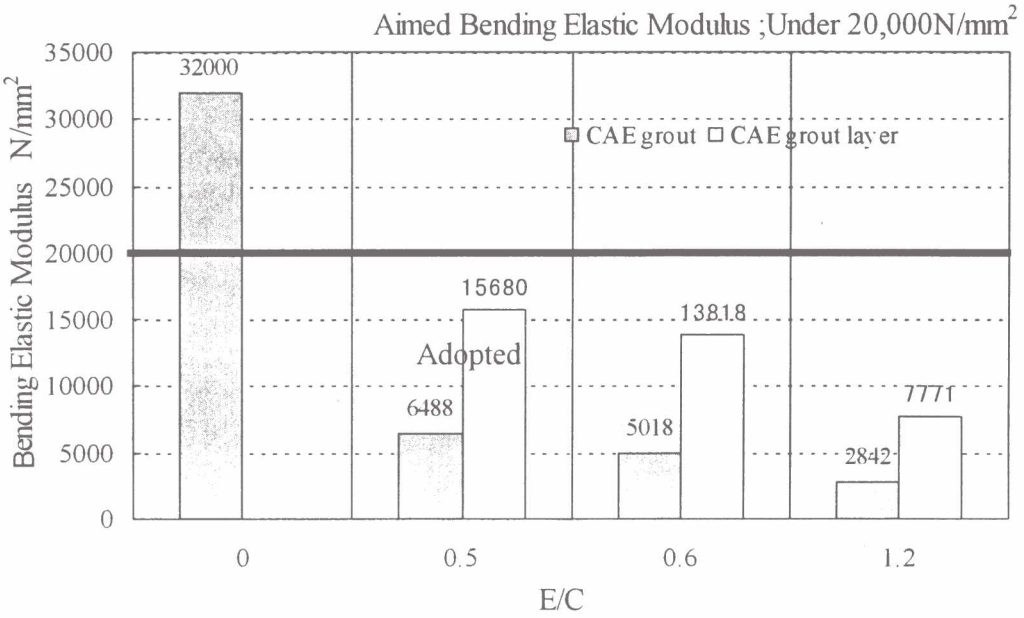


**Figure 4 Relation between E/C and Elastic Modulus of Flexure**

(3) Mix proportion for CAE grout
Table 1 shows the standard mix proportion (E/C = 0.5) and the aimed in-situ flow time of the CAE grout for application in the injection method. The "rapid-setting premix" shown in the table is a material in which rapid-setting cement, silica sand and setting regulator have been premixed. The content of setting regulator is adjusted to a suitable value so as to maintain necessary workability for operation for more than 30 minutes and to enable early opening to traffic (within three hours of curing) for repair works and in urban areas with strict traffic regulations.

**Table 1 Mix Proportion and Aimed In-situ Flow Time of CAE grout**

| Mix proportion | E/C | Unit quantity(kg/m$^3$) | | |
|---|---|---|---|---|
| | | Rapid-setting premix | Asphalt Emulsion | Water |
| | 0.5 | 1,014 | 304 | 347 |
| In-place Mixing Proportion | • Rapid-setting premix: 2 bags<br>• Asphalt emulsion: 1 can<br>• Water added: 20.5 kg | | | |
| Flow time (seconds) | 11±2 | JSCE-F521 (P type funnel Method) | | |

## 4. DESCRIPTION OF INJECTION METHOD

### 4.1 FEATURES OF THE INJECTION METHOD

The features of the injection method are summarized as follows:
① Blocks can be placed on injection spacers by stonemasons with a good accuracy as in the case of the conventional method.
② The strength of the CAE grout layer as substitute for the cement mortar layer is uniform, irrespective of the job conditions.
③ The CAE grout layer and the joints around blocks are filled with the same CAE grout and become integral.
④ Being high in shock absorption, the CAE grout is highly durable under repeated loads

of heavy vehicles.

⑤ As the CAE grout layer is flexible, the substrate need not be a concrete pavement. An asphalt pavement can serve as the substrate. This simplifies the construction work and contributes to cost reduction.

⑥ Using a CAE grout for rapid application enables early opening to traffic about three hours after construction. Figure 5 illustrates the pavement structure formed by the injection method having the above features.

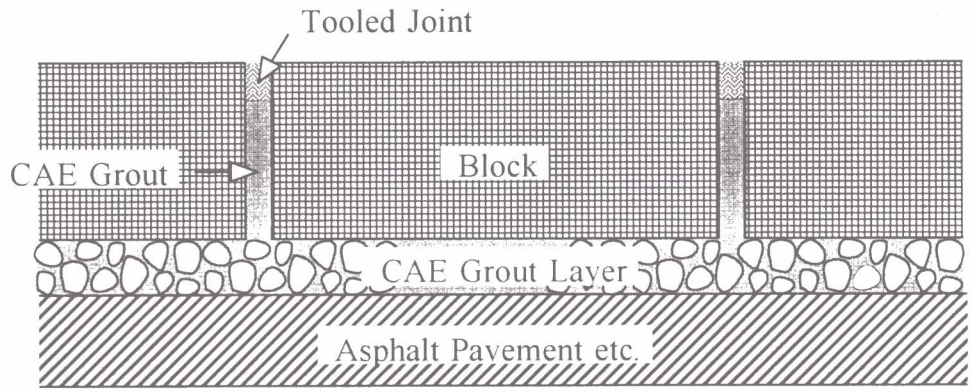


**Figure 5 Pavement Structure by Injection Method**

## 4.2 STANDARD METHOD OF CONSTRUCTION BY THE INJECTION METHOD

The method of constructing a block pavement by the injection method is as shown in Figures 6 and 7.

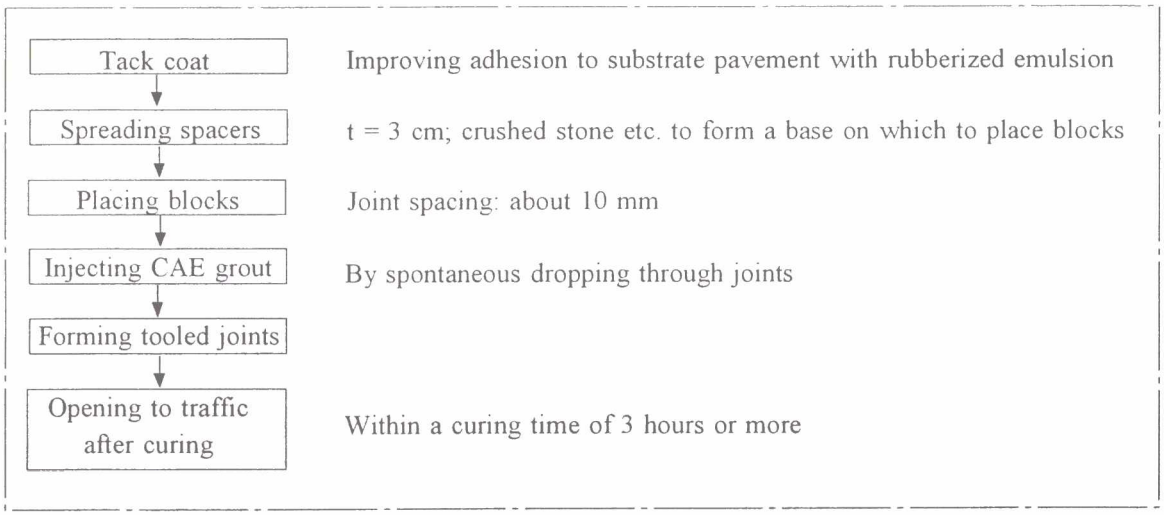


**Figure 6 Flow of Construction Work by Injection Method**

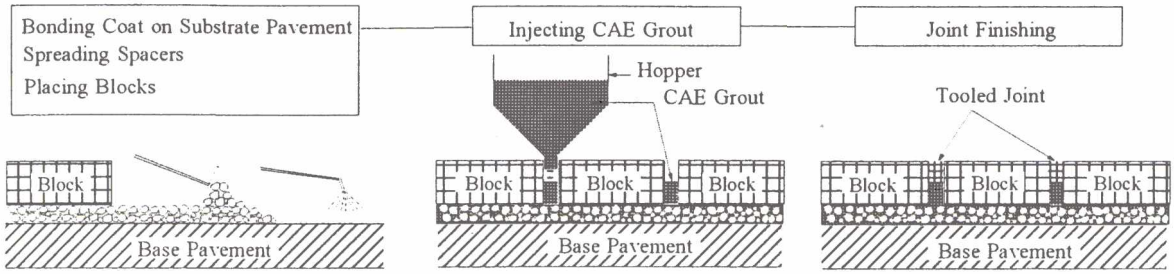


**Figure 7 Construction Procedure by Injection Method**

## 5. EXAMPLE OF CONSTRUCTION AND SERVICEABILITY INVESTIGATIONS

### 5.1 EXAMPLE OF CONSTRUCTION

Introduced here as an example is the block pavement constructed on the plaza in front of the A-Bomb Materials Exhibition Hall in Hiroshima Peace Memorial Park where the Atomic Bomb Dome known as a holy place for world peace and designated as a world cultural inheritance is situated. A great number of foreign tourists visit this place, and as many as 50,000 people including foreigners from all over the world participate in the Peace Memorial Ceremony held there every year on August 6.

The site is the parking lot for sight-seeing buses at entrance to the peace memorial park. The number of buses parking a day is 50-100 on average and about 250 in a busy season. Due to repeated manipulations of vehicles at parking, severe loads are applied to the block pavement.

The existing block pavement was constructed in 1989. The first repair by the injection method was made 7 years after its opening to traffic. The block pavement was formed by the conventional method, using cement mortar for the bonding layer and paving the old concrete pavement with concrete blocks (block size: 760 x 465 x 80 mm; paved area: about 3,000 $m^2$). As the job site was under severe loading conditions, blocks shaken due to damaged jointing mortar, and depressions or ruptures accompanied with a spurt of sand were observed at many places and, therefore, the serviceability of the pavement was adversely affected As a result of investigating the fracture spots, it was found that the concrete pavement, the substrate for concrete blocks, was not fractured. Only the cement mortar layer, the bonding layer, was fractured.

Based on the foregoing, the fracture of the block pavement was judged attributable to the cement mortar layer as the bonding layer, and it was decided to make repairs by the injection method. The repair work began in August 1996 and continued till 1999. During this four-year period, the fractured block pavement sections unable to withstand the service conditions were repaired at the rate of 200 $m^2$ per year, over a total area of 800 $m^2$ (the cross section of a repaired section is shown in Figure 8). Next, description is made of the serviceability investigations on the job site.

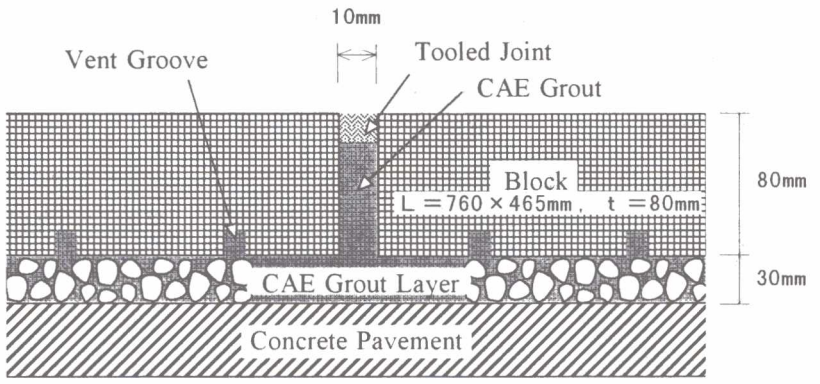


**Figure 8 Cross Section of Repaired Section in Hiroshima Peace Memorial Park**

## 5.2 SERVICEABILITY

In order to confirm the serviceability of the block pavement sections repaired by the injection method, serviceability investigations by visual observation and by deflection measurement by FWD were conducted in November 1999. Th investigations covered the four sections repaired by the injection method year by year since 1996 and the existing sections remaining in the state after construction by the conventional method.

・Visual observation

Notwithstanding the fact that the length of time from the opening to traffic till this investigation was as short as 50 months even in case of the first section repaired by the injection method, the repaired sections were kept in good state, without shaken blocks, damaged joints and roughened surfaces, under severe service conditions . On the other hand, though the existing sections generally maintained a good service condition, some of them showed damaged joints and shaken blocks and were incapable of withstanding long-term service conditions.

・Investigation by FWD

Figure 9 shows the results of deflection measurements made by FWD.

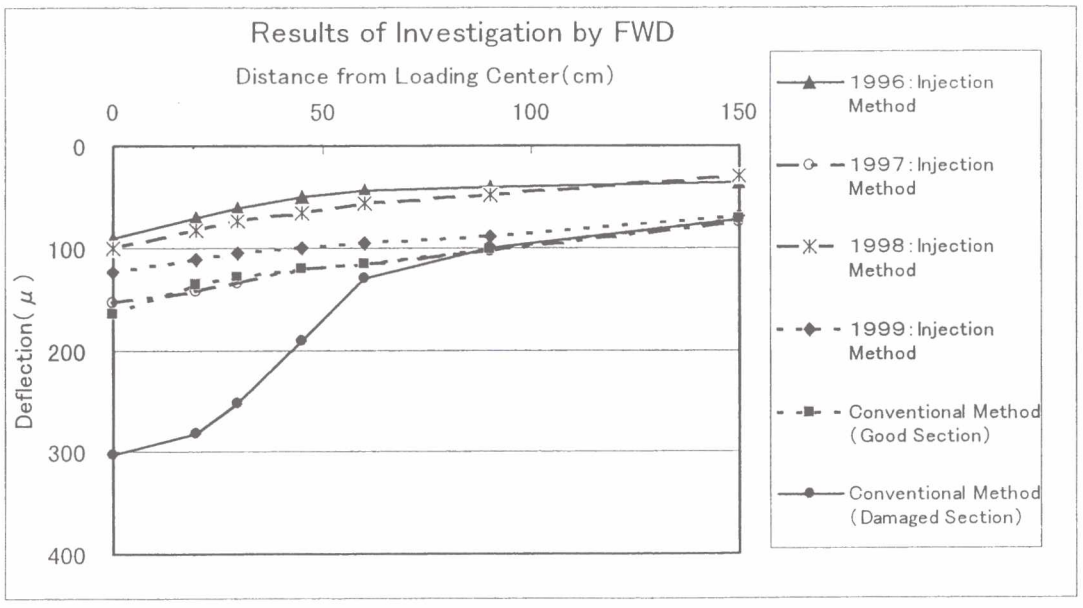


**Figure 9 Investigation by FWD in Hiroshima Peace Memorial Park**

The repaired block pavement sections showed almost the same results as the good ones of the existing block pavement sections, i.e., all of them followed the surface deflection continuously. On the other hand, the damaged ones of the existing block pavement sections did not follow the surface deflection continuously. The reason for this was presumed as follows. That is, the repaired sections and the good ones of the existing sections were continuously deformed due to close contact of the blocks with the base, while the damaged ones of the existing sections behaved independently due to poor contact of the blocks with the base.

Based on the obtained results of the serviceability investigations in the Hiroshima Peace Memorial Park, the following could be confirmed:

① The injection method is beneficial in improving the serviceability and durability of block pavements for roadways.

② Judging from the deflection measurements by FWD, the injection method makes it possible for block pavements to follow even a large deformation and is superior to the conventional method in the ability of block pavements to follow the deflection occurring under traffic loads.

## 6. CONCLUSION

Since its development in 1995, the injection method has been used at 70 sites (about 40,000 $m^2$) till February 2000. Of these, about 60 sites used this method in repairing the existing blockstone pavements. This unintentionally brings out in full relief the actual serviceability and durability conditions of block pavements constructed by the conventional method of Japan which uses cement mortar to bond and fix blocks to the base. Since 1999, the injection method has been finding increasing applications in new, large-scale construction sites, proving its usefulness

The injection method solves the problems with the conventional method of using cement mortar by means of applying a special asphalt emulsion-containing CAE grout to the bonding layer. It is an effective method of applying blocks to roadways on which heavy vehicles run.

We would like to further improve the injection method and establish an optimum design method covering the pavement structure.

## 7. REFERENCES

1. Shouji,K., et al. Development of new block pavement for roadways, Dorokensetsu, Oct.1997.

2. Tsuyoshi.T., et al. Structual evaluation of block pavement for roadways, 32-8.,Hoso,1997.