DEVELOPMENT OF NATURAL STONE COMPOSITE CONCRETE PAVING BLOCK

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SUMMARY

Though natural stones are widely used for a material of paving block, in its execution there have been arising several problematic issues including a prolonged term of works, difficulties in repair and recent tendencies of shortage of operating craftsmen, due to the wet type working method. The authors set to develop a new concrete paving block equipped with advantages of natural stones. After gone through several expriments, a paving block adhered to a base block having natural stones, with both advantages of those natural stones and concrete paving blocks, was commercialized and was achieved its industrial production framework.

1. Introduction

Recently, in Japan various kinds of paving materials for spectacle purposes have been widely used, but natural stones have come to be marketed, due to the fact that the materials have a longer durability, enabling a combination of surrounding landscape and atmosphere, as a paving material with excellent design capability. As a result, natural stones are consumed approximately a million m^ per annum. However, in contrast to its growing demands, several issues on execution of works, including a shortage of working craftsmen, a prolonged period of works, unavailability to open to use immediately after completion of works, have come to be considered gravely problematic.

In this light, the authors set to study for developing a new paving material incorporated with concrete paving block, which is more excellent against those mentioned issues than conventional working methods with natural stone paving, and natural stones as the ultimate paving material for spectacle purposes. Among several methods for unification of concrete paving blocks and natural stones, the authors succeeded in development and practical utilization of a new block unified with natural stones, with special mortar as an adhesive agent. The authors named the new material as Natural Stone Composite Concrete Paving Block (SCP). In addition, an automatic composite device was developed. This device realized several notable achievements of industrial production features including decrease of composite cost by reduction of labor, stabilization of product quality and conformity to several kinds of composite sizes.

This paper summarizes the development outline including the shape, physical properties, composite method and composite device of SCP as follows.

2. Problematic Issues and Countermeasures of Conventional Working Methods

As a result of arranging problematic issues found in conventional working methods such as natural stone paving and proposing solutions for each case of the problems, the authors compiled and then examined the following countermeasures proposal shown in Table 1.

Table 1 Problematic issues and countermeasures

No.	Problematic Issue	Countermeasure
1	Long preservation period at a site due to wet type working method	Make it precast concrete product
2	Little working capability due to too many working steps at a site	Adhere in the plant
3	Difficulty in partial repair	Realize repair by extract change
4	Occurring of blow up	Use sand joint
5	Unavailability in road way	Obtain stronger adhesive strength

As a result, the authors were able to solve the problems by utilizing advantages of the dry type working method unifying natural stones and concrete paving block. Furthermore, employing a thin plate of expensive natural stone, we found that development of an inexpensive natural stone paving material proved to be possible.

3. Shape of SCP

The shape, as shown in Figure-1, is composed of natural stone for the surface and the base block by a conventional concrete paving block. They are adhered firmly by way of a special mortar. The surface of natural stone was done with burner finish due to its roughness, and as for the thickness, a level of 20 mm, the thinnest one, was adopted because of its facility in burner finish.

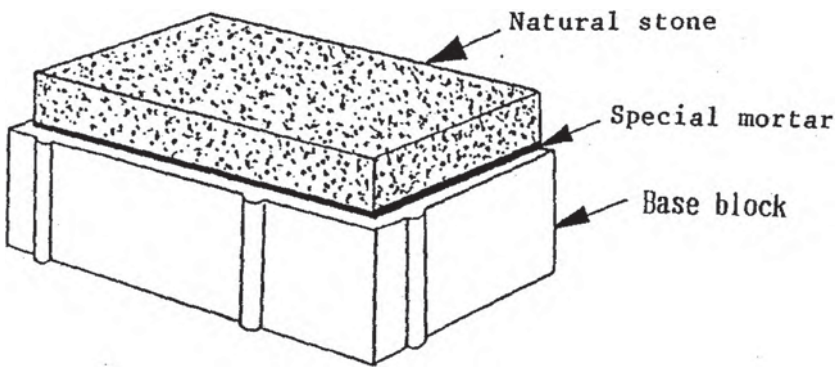


Figure-1 Shape of SCP

3.1 Shape of base block

The upper part of the base block has dish line depression, facilitating positioning at composing of natural stone. In addition, this block has a margin for prevention of breaks of the corners, caused by competition between adjacent blocks when traffic load is added on the block.

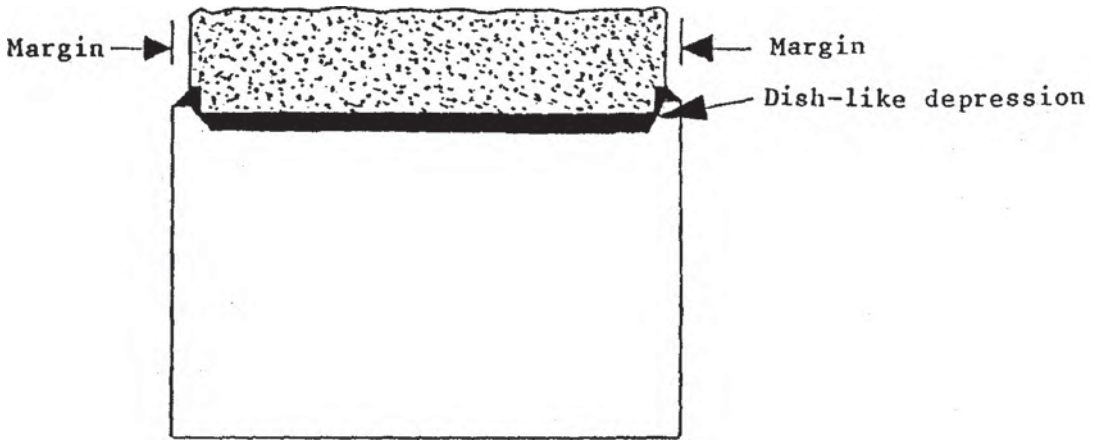


Figure-2 Cross section of SCP

4. Surface Design

For a natural stone used for the surface, granite, with excellent resistance for weather and abundance in colors, is used. Furthermore, physical properties, as shown in Table-2, fully satisfy the JIS standards specified for natural stones. Granite, having various characteristics, is one of the most desirable natural stone paving materials.

Table 2 Physical properties of granite

No.	Item	Granite	Standard (JIS.A.5003)
1	Compress ine strength (kgf/m^2)	1480	More than 500
2	Apparent specific gravity (g/cm^2)	2.61	2.6 - 2.7
3	Absorption (A)	0.35	Less than 5

4.1 Surface finish

The surface of natural stone secures safe walkability applying burner finish in order to magnify slipping resistibility which is an important element as paving stone. Burner finish utilizes exfoliation of the surface construction by deviation of thermal expansivity of different crystilized minerals constituting the stone construction, by means of heating the surface of the stone with burner flame. As the crystal structure of the surface exfoliates thinly, the surface becomes rough and increase slipping resistibility. The surface has a beautiful glossy finish.

4.2 Design capability

SCP can be applied to a variety of usage according to each design image depending on a combination of the surface finish of stone, surrounding finish and abundant sizes of products. By processed surrounding finish of a burner finish product, three kinds of finish products, of cutting finish, splitting finish and round finish, have been developed. Next, each feature of the burner finish products will be described as follows.

(1) Cutting finish: has a design of sharp appearance processed by thread face in the circumference and represents a gorgeous atmosphere for sophisticated urban pavement space. (Picture 1)

(2) Splitting finish: as shown in Figure 3 of natural stone, splits after cutting mechanically about one third of the thickness and provides natural split skin for the upper side or the surface. This finish provides nature! scent around walking space and its joint line of bold split skin adds and stirs up a sense of pastime for the surrounding street design. (Picture 2)

(3) Round finish: presents an ornament with soft and serene atmosphere, rounded in edges by burner processing. This even seems to generate a certain style akin to European stone pavements. (Picture 3)



Picture-1 Cutting finish



Picture-2 Splitting finish



Picture-3 Round finish

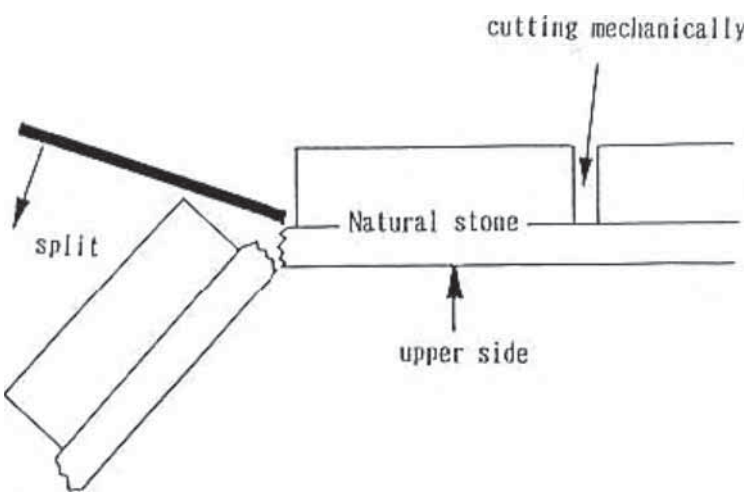


Figure 3 Processing method of natural stone for splitting finish

5. Composite Method

As stated in Introduction, when adhering a natural stone with the base block, the authors found by way of experiments that compression of natural stone, applying a special mortar to the prefabricated base block, realizes high bond strength and minimizes troubles (such as splitting) after operation. The composite method was determined after a number of experiments aiming at realizing industrial production. Summary of the composite method is described as follows.

(1) Mortar application to base block (Figure 4)
By moving of the mortar supply hopper, mortar is applied on the upper face of the base block via a specially shaped mask. At this moment, by adding vibration to the hopper, more homogeneous application became possible.

(2) Compression of natural stone and base block (Figure 5)
Adhere firmly by the simultaneous action of vibration and press, placing a natural stone on the base block applied with mortar. At this moment, the natural stone is positioned automatically on the center of the base block due to the dish-like depression of the base block.

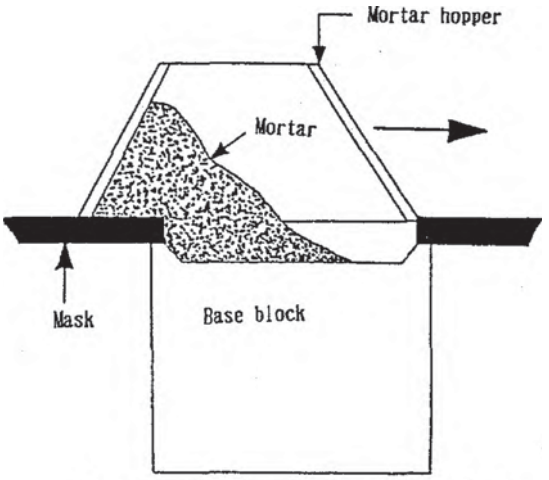


Figure 4 Motor application

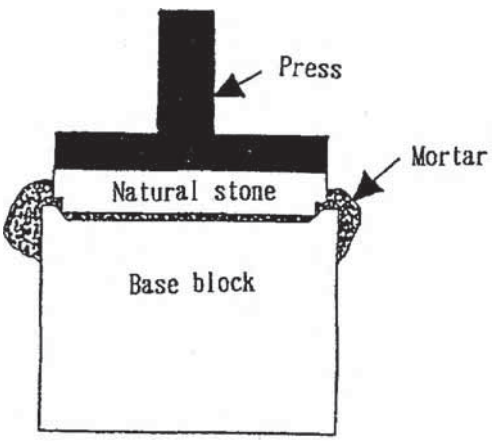


Figure 5 Compression

(3) Finish
Remove mortar with a scraper made of special material as the excessive mortar sticks around the compressed composite block. By removing of this excessive mortar, stains protection effects of the product were realized, as well as ornamental characteristics in the adhesive part of the composite block were elevated, resulting in enhancement of the product value of SCP.

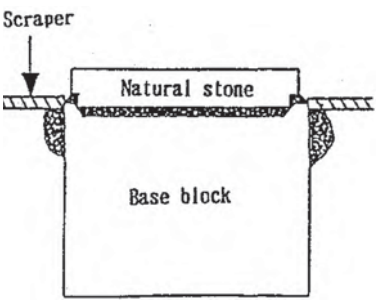


Figure 6 Finish

The above mentioned method lead to development of a composite device realizing mass production of the natural stone composite block.

6. Composite Device

In developing a composite device, the following design conditions were established.

(1) To mechanize all the stages of composite method and make possible automatic continuous operation.
(2) Number of operators of the device itself shall be one person.
(3) Amount of daily production shall be more than 200 m2.
(4) To be Applicable to several sizes.
(5) To facilitate maintenance.

Based on the conditions, the work process of the conposite device developed is as follows.

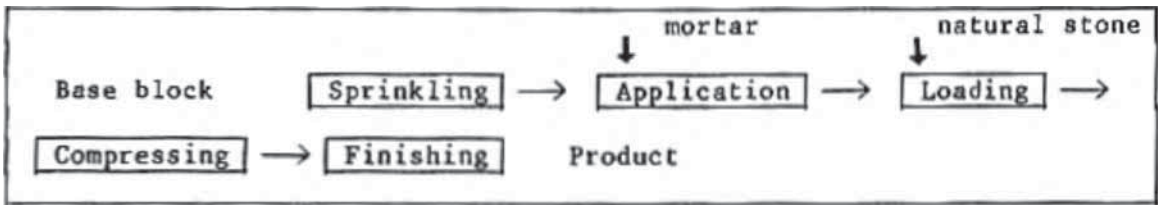
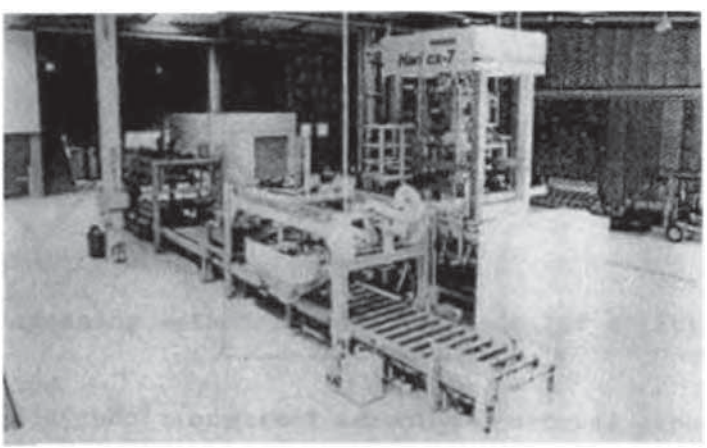


Figure 7 Work process of composite device

6.1 Outline of composite device

The base block on the pallet, set to the composite device, is carried to the device by a unit of six pieces and then receives mortar application. The base block set with natural stone is then sent to the compression process, being adhered firmly by the simultaneous action of vibration and press. After removing the excessive mortar at the finishing process, the device is lined on the pallet as a product. A wooden pallet for the base block can be used for a product by being automatically sent after removal of the base block. In addition, natural stone is stored in a dedicated container and is automatically loaded on the block after installed to the device including the overall container. Picture 5 shows ths whole appearance of composite device.



Picture 4 Whole appearance of composite device

6.2 Specifications of composite device

The specifications of composite device developed in compliance with the design conditions are shown in the following Table 3.

Table 3 Specifications of composite device

No.	Item	Specification	Note
1	Number of 1 cycle composite	6 pieces	Simultaneous composite of 6 pieces
2	Maximum composite size mm	200*300	Height of product: 90 mm
3	Minimum composite size mm	200*100	Height of product: 60 mm
4	Maximum production capability m^2/day	400	Operation hours: 8 hr/day
5	Supply of natural stone	Dedicated container	20 m^2/container (natural stone: 20 mm thick)
6	Operation method	Full auto	
7	Operator	1	Forklift operator needed
8	Facility power Kw	32	Composite device: 21 Kw Air compressor: 11 Kw
9	Compression time sec.	5-8	Differs depending on composite size

The reasons why a dedicated container for supply of natural stones is adopted derives from the following factors: (1) device will be compact, (2) by trans-shipping, check of inferior goods, such as splitting, during transportation can be facilitated.

7. Physical Properties

Physical properties of SCP manufactured with the composite device are described as follows.

7.1 Bond strength

A composite block, compressed with vibration and press for five to eight seconds at the compression process, shows an excellent bond strength of 17.5 kgf/cm^2, which is twice as intense as a conventional working method. Mix proportion of adhesive mortar is shown in Table 4.

Table 4 Mix proportion of adhesive mortol

Unit weight (kg/m^2)				
Cement	Water	Silica sand	SBR Latex	Methyl cellulose
628	218	1256	100	1.26

7.2 Inspection strength

In accordance with the experiment method defined in JIS A 5403, an experiment, which repeatedly drops a steel ball of 1 kg, from a height of 1.2 m, causes a hollow only on the impacted surface between the natural stone and the steel ball, but even after an experiment of dropping as much as 50 times no exfoliation or destruction of the natural stone occurred. This indicates a high bond strength between the natural stone and the base block.

7.3 Freezing and thawing

The result by the experiment method defined in ASTM C 666 proved the decrease ratio of bond strength was approximately 10% at the 300 cycle. Figure 8 shows the result.

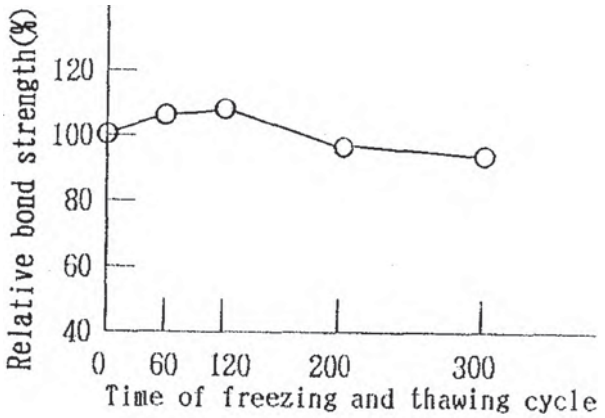


Figure 8 Freezing and thawing

7.4 Ablation resistance

In order to conduct a comparative investigation of ablation resistance, the rotation ablation test by a spike tire was executed for two types of SCP and an normal concrete paving block, under the conditions specified in Table 5. As shown in Figure 9, ablation level differs depending on differences of natural stones, but the SCPs are 10 to 40 times as much excellent as the normal paving block in terms of ablation resistance.

Table 5 Test conditions

Item	Test condition
Test material period	Two weeks
Test temperature	0°C at room temperature (during testing: sprinkling 150 1/h)
Times of running	50,000 times
Tire	3.50 - 5 spike tire, tacks: 76
Wheel load	100 kg
Revolution speed	Tire: 30.0 km/h, revolutions 24.5 km/h

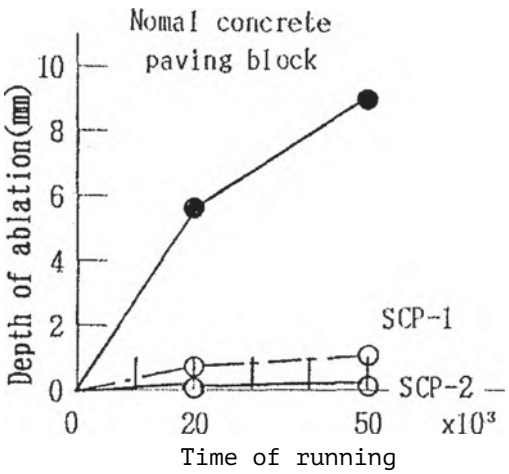


Figure 9 Comparison of depth of ablation

7.5 Slipping resistance

The slipping resistance value of the surface of natural stone provided with burner finish shows excellent resistance: 102 BPN at dry status and 69 BPN at humid status. The comparison with other paving materials, shown

in Figure 10, indicates almost equivalent result to asphalt paving

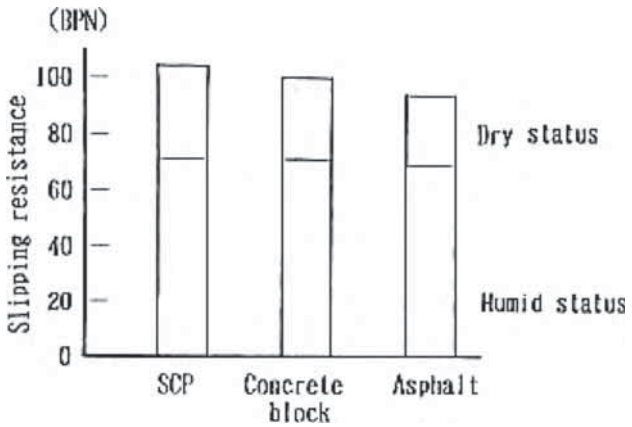


Figure 10 Comparison of slipping resistance

Table 6 Comparison of impact absorptivity

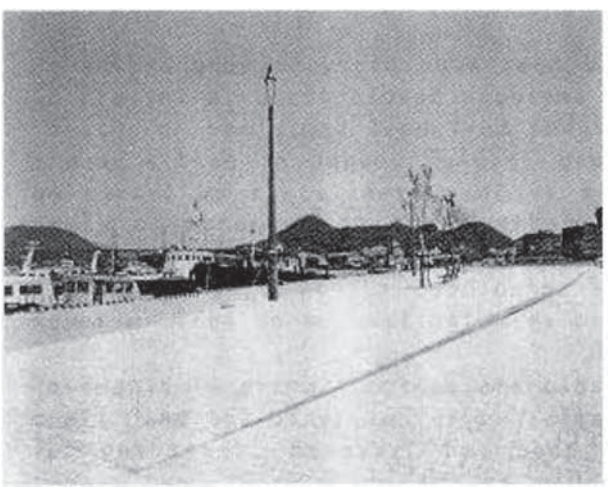
Type	Average height of repulsion
SCP	9.6 cm
Asphalt paving	12.4 cm
Concrete paving	20.9 cm

7.6 Impact absorptivity

A test of impact absorptivity measuring the repulsion height, dropping a steel ball from a height of 1 m, in order to investigate influences on human feet, in particular the knees, when applied to the pavement provided for walking and jogging. The test result, as shown in Table 6, indicates that SCP is a half of the concrete paving in impact absorptivity. This shows that SCP, due to its sand cushion layer in the paving structure, is excellent in impact absorptivity compared with other paving materials.

8. Examples of Works

Next, examples of works of SCP in Japan will be introduced with pictures .



Picture 5 Port of Moji (Splitting finish)
(Working square: 6,350 m?)

Picture 6 City of Kagoshima
(working square: 1,400 m^)

9. Conclusions

Through development of SCP which makes possible a conversion from wet type to dry type in terms of natural stone paving works method, the following advantages will be gained.

(1) Immediate opening up of the pavement after completion is possible due to no necessity of preservation period at a working site.
(2) Working capability per person increases four to five times asmuch as that of previous cases and reduction of laboi is attained.
(3) Repair can be done easily by extract change.
(4) By using sand joint, no blow up, caused by change of temperature,does occurs.
(5) High bond strength enables to use for a drive way.
(6) Development of a composite device realizes mass production of SCP with low cost and stable quality.
(7) A low cost natural stone paving becomes possible, and then effective utilization of resources will also be achieved.