DEVELOPMENT AND PRACTICAL USE OF JOINT SAND TO INHIBIT PLANT GERMINATION AND GROWTH ON BLOCK PAVEMENTS

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ABSTRACT

Under Japanese weather conditions or climates, the jointing sand of block paved pavements is likely to be a site for implantation of wind-borne seeds. Plants which grow from the jointing sand not only cause disfigurement of the pavements but also become a breeding ground for insect pests, thereby becoming disadvantageous to the management of these pavements. In some cases, problems arise concerning the safety of pedestrians.

Thus, we have developed joint sand which inhibits germination and growth of wind-borne seed plants but does not deteriorate the joint function in terms of interlock, nor does it have any negative impact on the environment. Further, we conducted a 5-year in-service test of our developed sand against untreated river sand which is generally used for practical roads. As a result, we established types and characteristics of plants typically found in block pavement joints. Further, it was observed that only 2% of plants in number grew in an area treated with the developed sand in comparison with plants grown in an area treated with conventional sand. There was no change to the components of the developed sand even after 5 years of service. This proves the sustained improvement to the developed sand.

1. INTRODUCTION

Block pavements which comprise bedding and joint sand, have a circulatory structure which infiltrates and evapotranspires rain water and air through the joints. Japan has a temperate climate, which provides a favorable environment to animals and plants.

Photo 1. Weeds growing thickly on block pavement surface.

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Therefore, there have been problems that weeds often grow through (from) joints of block pavements. The weeds in joints cause disfigurement and discomfort, and in addition, labor and material costs to remove these weeds are a considerable burden to road maintenance authorities. Further, conventional chemicals used for eliminating weeds are likely to cause environmental and sanitary problems, and their efficacy is not expected to last for a long period.

In order to solve these problems, we developed a completely new type of joint sand for block pavements which inhibits germination and growth of weeds.

2. ACTION MECHANISM

2.1 Reaction mechanism for Mejimall sand

We have developed a new sand which is named "Mejimall sand." The developed sand is prepared by allowing sand particles as a base material to react with water-based alkylalkoxysilan monomer penetrants. The reaction is described as follows.

2.2 Hydrolysis of alkylalkoxysilane monomers

Water-based alkylalkoxysilan monomer penetrants which were dissolved in water were applied to the base sand material, and thereby alkylalkoxysilane monomer (hereinafter referred to as silane monomer) of a major component was hydrolyzed thereby to form alkylsilanol.

2.3 Reaction with base material

The alkylsilanol produced by hydrolysis was reacted with silanol groups of the base material by dehydration condensation reaction, thereby making the base material hydrophobic. The series of reactions for hydrophobicity do not fill in capillary tube-like fine spaces among base materials, which differs from paints. Fig. 1 shows a reaction formula for hydrolysis.

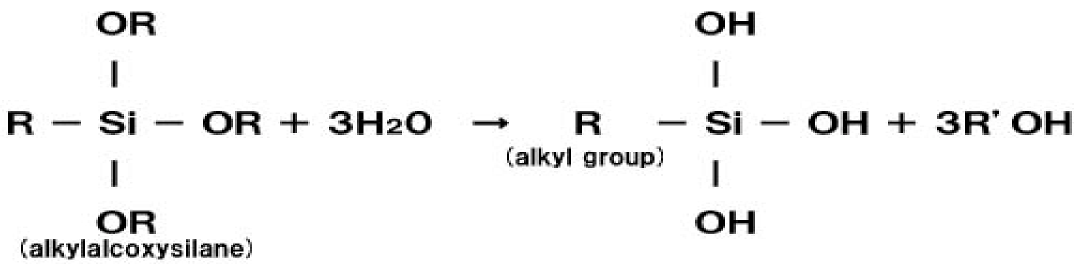

Figure 1. Reaction formula for hydrolysis.

2.4 Action mechanism of Mejimall sand

The action mechanism of Mejimall sand is to form a hydrophobic layer on sand particle surfaces by a chemical reaction between silane monomers and silanol groups of joint sand particles as indicated in the reaction formula. This reduces water retention of joint sand and expedites the drying of joint sand, and thereby water supply to weed seeds is cut off, resulting in inhibiting their germination. Also, even if the seeds do germinate, water will not be supplied to their roots so that they cannot survive. In other words, there is no direct action of Mejimall sand on plants. Further, the action of Mejimall sand is only to make sand particles hydrophobic. Mejimall sand does not either cause sand particles to adhere to each other or cause joint sand layer to cure. Thus, infiltration or evapotranspiration of rain water occurs as usual.

Mejimall sand is prepared and packed at factory by premix-coating silica sand with silane monomers for shipment.

2.5 Active component

An active component of Mejimall sand and its typical properties are shown in Table 1. The treated sand retains the original color of the base material and it is odorless.

Table 1. Typical properties of silane monomer.

Appearance	milk white liquid
active component	alkylalkoxysilane
pH at 5 °C	6 to 8
viscosity at 25°C (CP)	10 or less
specific gravity at 25°C	0.95
flashing point	flashing was not observed up to at 90°C

3. METHOD OF USE

Mejimall sand can be used in the same manner as conventional sand.

After block pavement is paved, Mejimall sand which is premix-coated in the dry condition, is spread over the block pavement and is broomed into the joints (jointing sand). Water spray is not necessary, and the construction process using Mejimall sand presents no additional costs over conventional jointing sand.

4. CONFIRMATION TEST OF HYDROPHOBIC JOINT SAND

Test conditions and methods were employed as shown in Table 2 to measure time-related water retention (moisture content percentage), and the results are shown in Table 3.

According to these results, it is confirmed that Mejimall sand has lower moisture content ratios soon after water spraying than joint silica sand and Mejimall sand dried faster over time following initial wetting.

Table 2. Test conditions and methods for water retention.

Item	Test conditions
Test container	Joint sand was packed with a thickness of 3 cm into a receptacle (7 cm in depth) having a hole on the bottom thereof.
Type of joint sand	Silica sand and Mejimall sand (both having a maximum particle size of 2.0 mm)
Test environment	Placed in a room with Temp.: 20 °C, Humidity: 60 %
Test method	(a) Water was sprayed until water seeped through the bottom of receptacle. (b) Moisture content percentage was measured just after the process (a). (c) Moisture content percentages were measured after 5 hours, 1 day, 2 days, 5 days, and 10 days.

Table 3. Results of water retention test.

	Moisture content percentage (%)					
	soon after water spray	after 5 hours	after 1 day	after 2 days	after 5 days	after 10 days
Mejimall sand	8.7 (100%)	8.1 (93%)	6.9 (79%)	5.2 (60%)	0.8 (9%)	0.0 (0%)
Silica sand	19.4 (100%)	18.7 (96%)	17.9 (92%)	16.0 (82%)	10.0 (52%)	5.0 (26%)

*The figures in brackets are differential percentages representing the changing moisture content with time, expressed as a function of the initial wetted condition.

5. FIELD APPLICATION INVESTIGATION

The field trial of Mejimall sand was carried out in the construction of a cycle road and pedestrian way, which was started in March, 1996. A trace investigation was conducted over the subsequent 5 years.

5.1 Outline of construction

- Total construction area: block pavement 526.2 m^2
- Treated area for weed growth inhibition: 192.0 m^2
- Start date: middle of March, 1996
- Layout of construction site: shown in Fig. 2

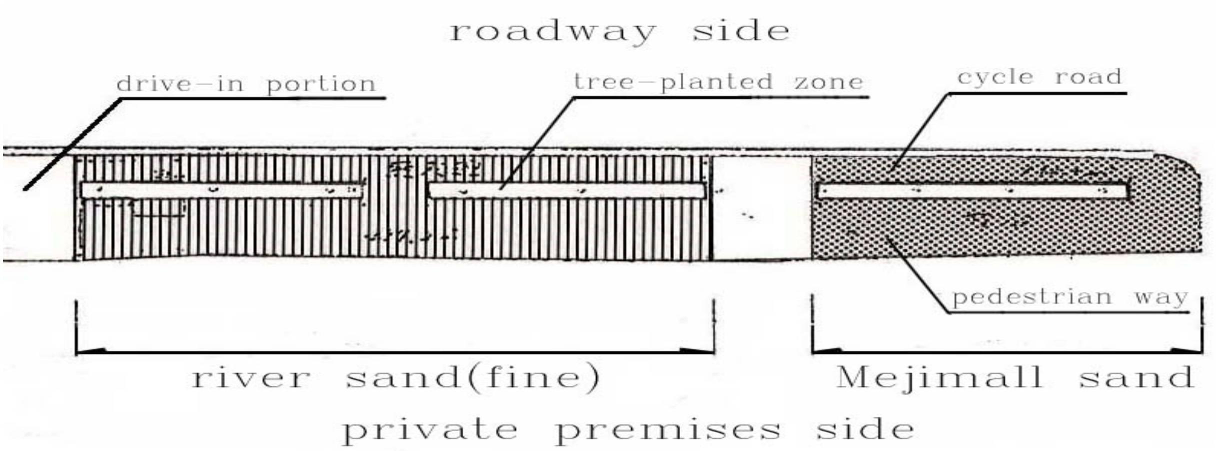

Figure 2. Layout of construction site - pedestrian way.

5.2 Construction method

As a joint material for block pavement, it is desirable to use dried silica sand from a viewpoint of workability. In this test, comparative examination was made on Mejimall sand and river sand (fine).

5.3 Items to be investigated

For the investigation on effects of Mejimall sand in this field trial, observation was made on the following points.

- Average number of germinated plants per 100 m^2
- Kinds of weeds
- Visual observations

- Comparison of hydrophobic properties of developed joint sand
- Weather conditions during the test period of 5 years

Table 4. Changes in numbers of germinated plants per unit area.

		1996.6	1996.8	1996.10	1997.3	2001.5
Mejimall sand (192.0 m^2)	Total number	0	2	4	19	72
	No. per100 m^2	0	1	2	10	38
River sand (334.2 m^2)	Total number	146	70	447	2760	6380
	No. per100 m^2	44	21	134	826	1909

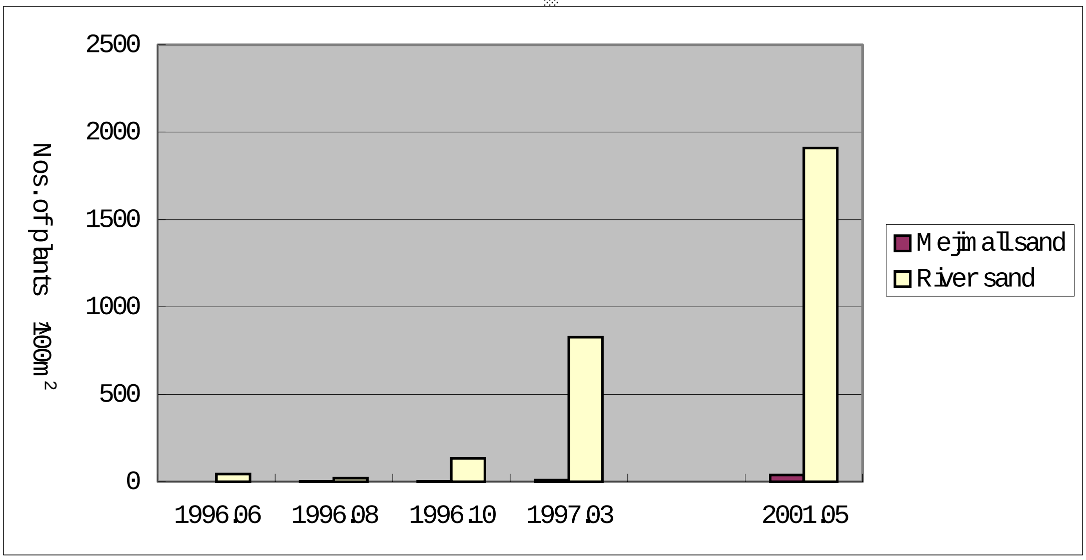

Figure 3. Nos. of germinated plants per unit area (per 100 m^2).

According to Table 4 and Fig.3, Mejimall sand area had 2 % of the number of germinated plants per unit area compared with river sand area after 5 years since the field trial started. A remarkable difference was, therefore, evident.

5.3.1 Kinds and nature of major weeds

Kinds and nature of major weeds are shown in Table 5.

According to Table 5, the characteristics of weeds which germinated in both areas are: reproduction by seeds; resistance to dryness; and strong reproduction. *Amaranthus lividus* and *Setaria viridis* germinate in spring, and they typically thrive in arid conditions. Further, they germinate soon after dropping their seeds on soil. *Rumex japonicus*, *Youngia japonica*, and *Erigeron canadensis*, which survive through winter, are resistant to dryness and have prolific reproduction too. That is, in Mejimall sand area, water necessary for weed growth is hardly supplied, and therefore only plants suited to dry conditions survive. However, weeds growing from joints of block pavements have a limit on their growth because of narrow joint width of 2 to 3 mm, and thus their height is also considered to be limited.

Table 5. Kinds and characteristics of major weeds.

Name	Mejimall sand	Non-treated	Reproduction method	Nature	Growth (cm)
Rumex japonicus	●	●	Seed and root regeneration	Roots close to ground surface have strong reproductive power	60-100
Youngis japonica	●	●	Seed	Hardly grow in wetlands. Not grow gregariously.	50-100
Amaranthus lividus	●	●	Seed	Germinates soon after seeds are dropped.	30-60
Poa annua		●	Seed	Most germination occurs in soil layer at a depth of 1 cm or less. Unable to germinate at a depth of 4 cm or more. Life span of seeds is short, 1 to 2 years.	10-30
Setaria viridis	●	●	Seed	Easily grow in dry lands	50-80
Erigeron annuus		●	Seed	Often grow in rather wet place, but do not grow in highly moisture condition	80-120
Cerastium fontanum subsp		●	Seed	Grow in a place without human influences	20-40
Veronica persica		●	Seed	Have strong competitiveness	50
Conyza sumatrensis		●	Seed	After flowering, crown hairs grow and seeds are scattered by wind, then soon germinate	200
Taraxacum officinale		●	Seed and root regeneration	Have high distribution rate because seeds are produced by parthenogenesis	5-25
Sagina japonica		●	Seed	Limit depth for growth is 2 to 3 cm, and usually grow from a point closer to ground surface	5-25
Echinochloa crus-galli		●	Seed	Seeds have dormant period and do not germinate soon after maturing. Short life span for seeds: one and half years. Well germinate at 15 to 25 °C. Relatively strong in dry condition. Germinate in deep points.	50-100
Erigeron canadensis	●	●	Seed	Germinate at 20 to 30 °C with light.	100-200
Erigeron philadelphicus			Seed and root regeneration	Germinate in rather wet place. Seeds have crown hairs and scatter by wind. No dormant period for seeds, and soon germinate after dropping on ground	50-100
Moss		●	Spore		

Note: The symbol "•" indicates weeds which were observed.

5.3.2 Visual investigation

In the Mejimall sand area, a range of weeds were observed. It is considered that soil was carried to the test area by wind from vacant lots or agricultural fields. The soil was deposited against projecting plants or recessed portions of the block pavement, and then seeds were wind-blown thereon and subsequently germinated.

In contrast, various kinds of weeds, which had hibernated during winter, started to germinate and grow in the river sand area, because the investigation was conducted early summer. Most of them germinated and grew from joints within the block pavement. Further, there were some parts, wherein mud was deposited in some joints and moss and the like were propagated.

Photo 2. Cover shot of Mejimall sand treated area.

Photo 3. Cover shot of untreated section (base river sand)

The following points can be mentioned concerning the general environment of the field trial site.

The test areas were located in so-called gardening town, and thus there were many garden trees and plants. Also, the pedestrian way was planned so as to have many trees planted therein since the area around this pedestrian way was designated as an area to provide good amenity to local residents with a focus on the environment. Further, since this pedestrian way is a strolling road, there were not necessarily many pedestrians. Thus, it can be said that the test site was a most suitable one for the promotion of plant growth.

5.3.3 Comparison between Mejimall sand and river sand in particle size and water retention
A) Test on particle size of joint sand
Particle size tests were conducted in the laboratory on joint sand samples taken from the test area after 5 years. Results are shown in Table 6.

Table 6. Results of sieve analysis on joint sand after 5 years.

Type of sand	0.075 mm	0.15 mm	0.3 mm	0.6 mm	1.2 mm	FM
Mejimall sand (%)	1.2	2	65	72	97	1.64
River sand (%)	5.7	27	75	87	93	1.18

Table 7 shows the particle distribution of Mejimall sand.

Table 7. Results on sieve analysis and filler on jointing sand at time of construction.

Type of sand	0.075 mm	0.15 mm	0.3 mm	0.6 mm	1.2 mm	FM
Jointing sand (%)	0.1	1	11	81	100	2.07

After 5 years the untreated river sand contained more particles with a size of 0.075 or less (filler) than Mejimall sand, and according to FM values, it is considered that the river sand had become finer across its grading.

An obvious time-related difference Mejimall sand exhibited was that particles passing 0.3 sieve increased. When joint sand samples were collected, mud or soil which was considered to have drifted from the surrounding areas, was deposited on joint surfaces with a thickness of several millimeters. However, almost clean dry silica sand appeared from layers below mud or soil. Therefore, it is considered that this layer had a great influence on the increase in particles passing 0.3 mm sieve. This is also proved by the fineness modulus. Since we observed that silica sand was not washed away from joints and that silica sand lower in the joints was dry, we consider that water repellency effect of joint sand was unlikely to be affected by rain water i.e. no leaching of repellant.

B) Water retention test on joint sand
According to the test conditions and methods shown in Table 2, time-dependent water retention was measured. Results are shown in Table 8.

Table 8. Result of water retention ratio.

	Water retention ratio (%)					
	soon after	5 hrs.	1 day	2 days	5 days	10 days
Mejimall sand	8.0	6.7	1.9	-	0.0	0.0
River sand	37.1	35.2	27.8	-	3.9	0.2
Mejimall sand before construction	8.7	8.1	6.9	5.2	0.8	0.0

Table 8 indicates that no change is observed in the water retention properties of Mejimall sand after 5 years.

5.3.4 Weather conditions during past 5 years
Figs. 4 and 5 shows monthly average atmospheric temperature and monthly average precipitation in the test areas during the past 5 years.

The changes of monthly average atmospheric temperature show that summer average temperatures during the test period were higher than that in average year. Also, winter average temperatures tended to be higher.

The monthly precipitation during the test period was obviously higher than that in average year. Here, summer precipitation for every year of the test period has an outstanding peak compared with the average year, and this was caused by the influence of typhoons. There are records indicating that rainfall from these typhoons caused damage by flooding in many places in the prefecture.

Considering these increases in temperature and precipitation, we can have a glimpse of global warming which is a recent topic, but this provides an environment more conducive to weed propagation. For example, *Erigeron canadensis*, which germinated and grew in any place during the test period, has the following germination condition. When the temperature is 20 °C to 30 °C and in the presence of sunlight, it germinates readily. Many of other weeds also germinate, when the temperature is 10 °C to 25 °C and the sunlight is sufficient.

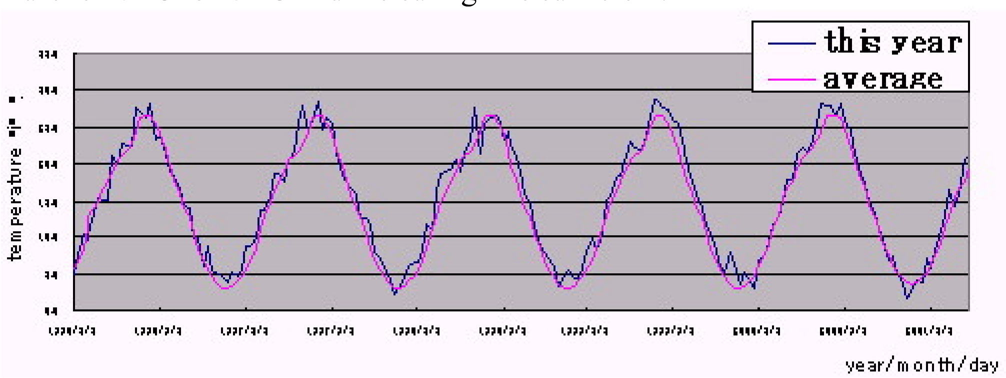

Figure 4. Monthly average atmospheric.

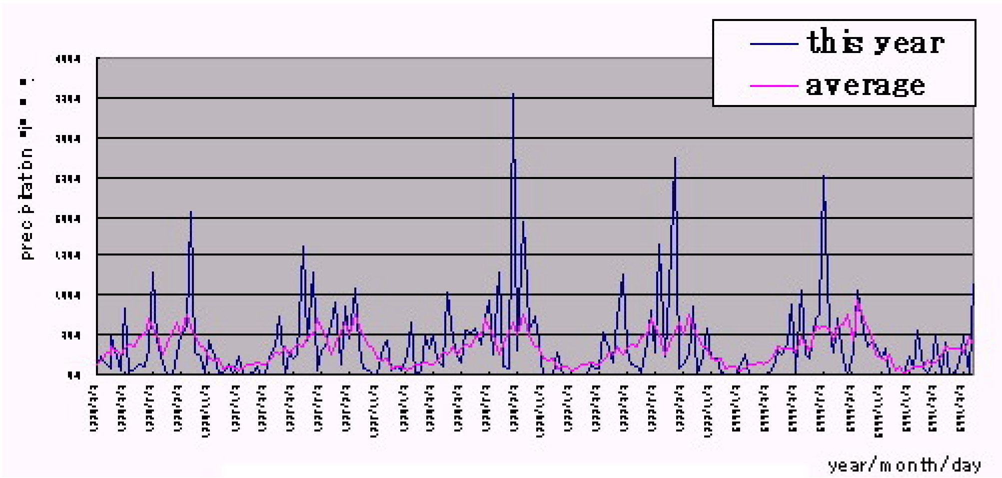

Figure 5. Monthly average precipitation.

6. SUMMARY

According to our investigation, we have found the following points.

- With respect to the number of germinated plants per unit area of 100 m^2, the results were the same as those of the past investigations, which were conducted during the first year since the investigation started. After 5 years have passed, a remarkable difference is observed between Mejimall sand area and river sand area. In particular, Mejimall sand area had only 2 % in number of germinated plants compared with river sand area.
- Almost all the weeds germinated in test areas were weeds which propagate from seeds. Weeds which propagate through root regeneration were hardly observed. This indicates that plants capable of growing in joints of interlocking blocks are plants whose seeds are wind borne.
- As for weeds that succeeded in growing in the Mejimall sand area, relatively more dryness-resistant weeds were observed than other types. Thus, it is considered that the use of Mejimall sand reduces water retention of joints.
- Mejimall sand has kept its hydrophobic property with almost no change even after 5 years. Although it was not consolidated, almost no washing of joint sand was observed. Thus, it is considered that Mejimall sand is unlikely to be affected by wind and rain over time.
- According to the past 5-year weather data, the changes of average monthly atmospheric temperatures were almost the same as those in an average year, but the highest average atmospheric temperature in summer and the lowest average atmospheric temperature in winter were prone to be higher. Also, though there were variations in precipitation during the 5 years, the precipitation in the test period was recognized to be higher than the average figure.

  These factors provided a suitable environment for plant growth. Even in these conditions, use of Mejimall sand reduced the number of germinated weeds.

7. COST PERFORMANCE

The publicly announced price of Mejimall sand is about 1 US$/kg. In general, about 4 kg of jointing sand per square meter are used, and the cost of Mejimall sand for 1 m^2 is about 4 US dollars. In recent years, dried silica sand has cost about 1.5 US$ for 1 m^2. The cost of Mejimall sand is about 2.6 times as high as that of dried silica sand. However, in the case of Mejimall sand, a user can save the cost for weeding twice a year (spring and fall, for each season weeding costs about 4 US$/$m^2$) and prevent disfigurement. In view of these points, it is considered Mejimall sand will pay for itself at an early date. This is proved by the past shipping record of Mejimall sand, which shows that about 150 tons of Mejimall sand per year are shipped. The shipping amount has increased year by year.

8. CONCLUSION

This investigation clarified kinds and characteristics of weeds capable of growing in joints of interlocking block pavement. This may be an initial investigation concerning control measures against weeds, and provide fundamental data on weeds which grow from joints of other types of dry construction. Further, it is found that Mejimall sand has been effective in controlling weeds for at least 5 years. We will conduct follow-up investigations, and observe the Mejimall sand area to establish how much longer the effect of Mejimall sand can be expected to perform effectively against plant invasion.