

Conservation of Historical and Archaeological Monument in Indonesia

by Samidi

Restoration of monuments in Indonesia has been carried out for several decades. Many temples have been restored since the Archaeological Service, the "Oudheidkundige Dienst", was formed. At the same time, a store of experience has been obtained. Continuous discussions on the principles and methods of restoration have been conducted among archaeologists, with the result that standard restoration methods have been firmly established.

The recent restoration of Borobudur used not only modern technology but also the previous principles and methods. Of course, some techniques were modified to systematize and to make them more practical, such as developing a registration system and precise sequences of dismantling and rebuilding.

On the other hand, conservation supported by scientific data only began with the restoration of Borobudur. Conservation science

was a new branch in the area of preserving Indonesia's historical and archaeological heritage. Hence, prior to its use, conservation science had to seek a proper method that would be both effective and in



A Buddha head on top of the Borobudur Monument.

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accordance with archaeological principles.

Although principles, guidelines and methods of conservation already exist in developed countries, they could not be applied directly in Indonesia due to differences in local conditions. In general, Monumenten Ordinance 238/1931 viz. article 5, paragraph 1 was used as a guide for conservation practice. However it was not sufficient to plan the field application.

Therefore, in this paper, I will describe our limited experience obtained from the conservation of Borobudur stones during the recent restoration.

For convenience, the paper is divided into two parts: 1) Conservation of Borobudur stones during the recent restoration; 2) Discussion.

Conservation of Borobudur Stones

Since Borobudur was rediscovered in the early nineteenth century, attempts toward maintaining and clearing it have been made continuously. A partial restoration was undertaken in 1907-1911 to strengthen the corners, to ensure better drainage of rainwater, and to repair balustrade gates and stupas. From a technical point of view, the restoration can be evaluated as successful, but archaeologically, less so because a great many parts of the structure were not put back to their original places and positions.

Observation during the next few decades showed that the deterioration of the stones and damage to the edifice continued unabated. A close look revealed new cracks. The coating that had been used to create harmonious color for photographing reliefs caused dilatation of the stone surface. Damage from structural tensions due to rain water that penetrated the subsoil inside the structure was observed mainly in sagging and leaning walls. The cement used in the restoration was soluble in rain water, causing harmful effects on the stones. Microorganisms grew profusely on the stones with high

moisture content; and observation revealed that some of them i.e. lichens and mosses had played a dominant role in further stone deterioration.

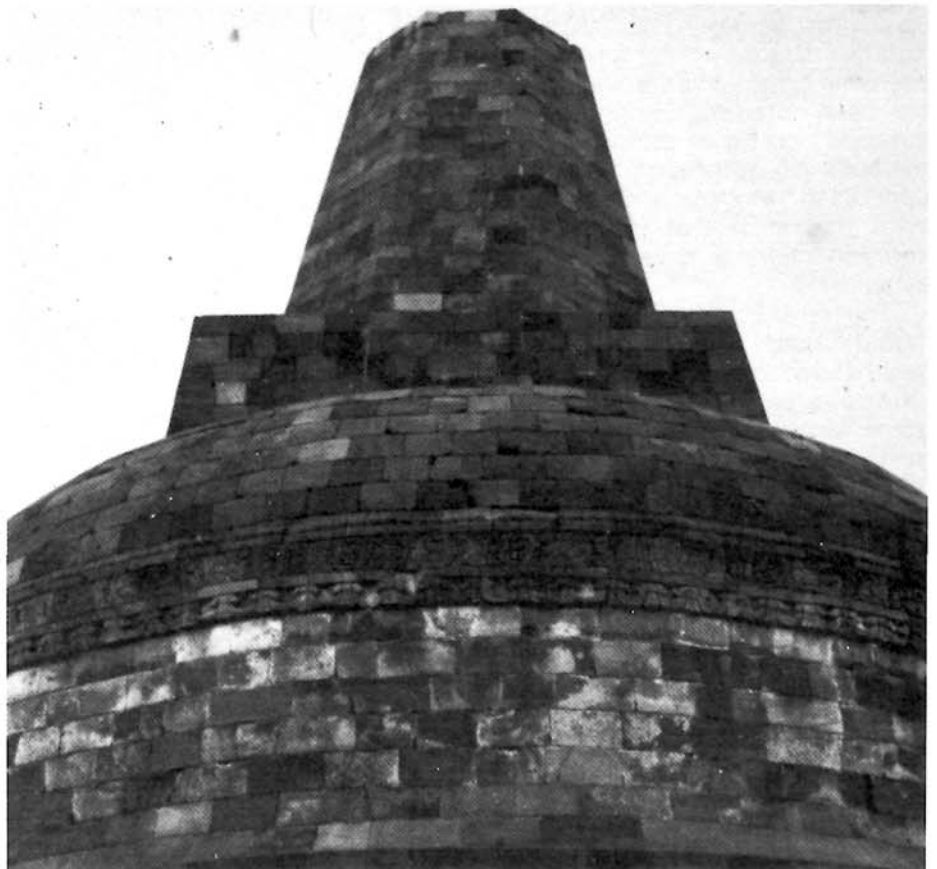
It became apparent that the 1907 restoration had not sufficiently provided adequate protection to the monument. Another total restoration was judged necessary to achieve the goal of safeguarding and preserving the monument for another 1000 years. The second restoration which was only completed this year aimed to halt the deterioration of the stone, to bring the monument as near as possible to its original state, and to take such measures as to make normal maintenance sufficient in the future in preventing a recurrence of the dilapidation.

The restoration was carried out by dismantling the structure. The stones were treated in the workshop, while in the remaining parts of the monument, activities were con-

ducted to decrease humidity by installing reinforced concrete slabs, a drainage system, and a water-tight layer. After all the systems had been put in place and precautions had been taken, the stones of the gallery walls and balustrades were rebuilt on the levels and in the positions which, according to previous computations, represented an accurate reconstruction of the monument. In this paper, however, only the conservation practices will be discussed.

Conservation Principles and Related Research

The term "Conservation" generally refers to the subject of care and treatment of artifacts, with the goal of preventing their further deterioration. As a discipline, Conservation means the control of environmental conditions to minimize the potential decay of artifacts, treating them to arrest existing decay and stabilizing them as far as pos-



The main stupa of the Borobudur Monument.

sible against further deterioration. There are some principles of conservation that should be followed. Three of them are as follows: the procedure should be reversible so that the desired objects can be returned to the pre-treatment condition; as far as possible, the decayed parts should be conserved, not replaced; and the natural patina of objects should not be removed.

General stone conservation processes are classified into three main treatments: cleaning, consolidation, and protection¹. This division not only arranges the processes in smaller and more manageable classes but also signifies that stone treatment should be seen as an ordered sequence of operations. Each treatment should satisfy different requirements. Conservation processes should be preceded by the identification of the deterioration processes, then cleaning followed by consolidation should be done only when they are required. Finally, protection can be applied to the stone itself as well as to the structure to modify potentially destructive factors in the environment².

G. Torraca, an Italian expert on stone conservation, formulated the following principal requirements for the stone cleaning process:

- a. It should be possible to regulate the cleaning action at will.
- b. The cleaning process must not produce any results which may cause future deterioration.
- c. The cleaned surface must be, as far as possible, smooth and free from cracks and other defects that could result in the acceleration of weathering rates.

He also agrees with the principle that the function of consolidation processes must be limited to re-establishing cohesion, where the stone has lost it to such a degree that its physical survival is imperilled. Cracks must be filled and fragments which have become separated must be rejoined by the use of adhesive, so that a basic conservation requirement, i.e. that

the stone be homogenous and present a compact surface to the aggressive action of the environment, can be fulfilled³.

Furthermore, reference may be made to the International Charter for the Conservation and Restoration of Monuments and Sites — ICOMOS — 1966, which was accepted during the last meeting of the SPAFA Workshop on Techniques of Restoration of Monuments. Article no. 10 says that traditional technique for conservation can be used when its efficacy has been shown by scientific data and proved by experience. An understanding is implied here that conservation measures should be effective, on one hand, and done in the simplest way, on the other.

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Conservation measures in principle should be as effective and long lasting as possible, but must have no side effects on the stones such as changes of property, discoloration, etc. as well as on the environment. This means that materials and methods to be used for conservation must seek the proper balance between effectiveness and retention of authenticity.

The conservation of Borobudur stones is done based on the above principles. It is also in accord with requirements stipulated by archaeologists⁴. To fulfil these requirements, a series of intensive studies on conservation has been carried out continuously since 1969 by Indonesian staff in collaboration with foreign experts. The objective of the studies has been to choose a proper method of conserving the

Borobudur stone. The studies have also involved identification of the types of stone⁵ and deterioration processes and causes plus selection of materials and conservation methods.

Parameters tested to assist in choosing materials include such matters as:

1) Cleaning and preventive treatment: effective at the lowest concentration, innocuous for the stones as well as the environment; long lasting effects in retarding the growth of micro-organisms. 2) Consolidation and repair: reversibility of the process, good adhesion; stability within its environment; possession of physical properties similar to the original stones.

Related Studies

It is necessary to point out that the previous investigations proved that the use of cement produced dangerous effects on the stone of Borobudur. That was why in the recent restoration, it became necessary to change the adhesive used in stone repair from portland cement to synthetic resin.

The studies have been carried out in the laboratory as well as in situ for comparative purposes, since conservation measures have not always been successful. Thus the use of "caution" in their application is appropriate. Chemical products which seem good under laboratory conditions, for instance, may prove ineffective or harmful in practical use owing to environmental factors affecting the condition of the stones. In this connection, data on the environmental conditions to which the monument is exposed such as thermic ranges, relative humidity, rain, direction of the wind and sunshine have also been recorded.

Results of the studies have revealed that cleaning is necessary to eliminate microorganisms as well as other deposits resulting from deterioration processes or from the environs of the monument. Cleaning should be done as far as possible in the simplest way, only by using water. The use of chemicals

is acceptable only when water proves to be insufficient. When used, they should be thoroughly washed off later. Consolidation by means of impregnation is considered to be unnecessary, since the stones are still strong enough. The separated fragments only have to be repaired and rejoined. Of course, preventive treatment has to be performed on the cleaned and repaired stones also. This Conservation process used for the Borobudur stones are elucidated in the succeeding paragraphs.

Conservation Practise

The dismantled stones of Borobudur were transported from the monument to the buffer storage for further determination of their order of conservation. When the stones arrived in the workshop, they underwent diagnosis for which purpose a treatment card was prepared. For practical reasons, the diagnosis was not oriented toward the type of deterioration, but directly to the type of treatment which needed to be done. The types of treatment comprised: dry cleaning; wet cleaning-manual cleaning; cleaning of biological material; cleaning of salt deposits, scraping, cleaning of pustules, and washing with water; drying, dowelling, filling, restoring, injection, and camouflage; laying out, and preventive treatment. These steps are described as follows:

Dry Cleaning This comprised several activities: scraping off the cement used by the Van Erp restoration and the clayish deposits on the sides of the stones only, by using compressor driven tools or hard tools. The deposits were carefully removed in order not to damage the stone; removal of organic growth i.e. higher vegetation like spermatophytes, pteridophytes, moss etc. by a wooden spatula or by hand; and removal

of paint used in registering the stones during the dismantling with Aceton, or benzene.

Wet Cleaning. The stones were cleaned by washing them with water, brushing, and applying chemical when necessary.

Manual Cleaning. Stones were washed with water and brushed with *ijuk* (palm fiber) brushes to remove dust, remains of clay and



several kinds of organic growth like algae and mosses which can be easily removed without the use of chemicals.

Cleaning of Biological Material. After the manual cleaning, pockets or debris of lichens, algae, mosses and salt deposits remained. Even the most rigorous manual cleaning was not sufficient to remove them, especially the debris. To facilitate the disposal of organic remains, a mixture of chemicals (called AC 322⁷) developed by P. Mora and L. Mora was used.

The chemicals were mixed together, and then a quantity of clay was added to form a paste. The paste was applied to the organic remains by means of a brush to a

thickness of approximately 0.5 – 1 cm. and was allowed to remain for 24 hours. After that, it was removed by means of spatula, and at the same time, brushed off and rinsed with water.

Cleaning of Salt Deposits. Salt deposits were found on the surface of the reliefs, in the cracks or at the joints of the stone blocks. Sometimes the deposits appeared to have covered Van Erp's coating. Deposits, mainly consisting of salts of silicate and carbonate, were found by chemical or biological processes. In some places, salt deposits formed through concretion, efflorescence, and subflorescence.

Total cleaning of salt deposits was impossible since they were much harder than the stone and highly compact. Moreover, such an endeavor would be technically very difficult and even harmful to the stone itself. Nevertheless the occurrence of salt deposits had to be reduced, especially the salt which totally covered the surface and plugged up the pores, to allow the evaporation of moisture.

To remove soluble salt, several methods were used.

The first method, which had a double function, used AC 322. According to the experiments by P. Mora and L. Mora on stone treatment in Europe, this chemical product augments the solubility of the salt which was washed off with water. Another method which was sometimes applied was the use of paper pulp or demineralization through a water bath.

Scraping. Scraping of salt concretions was done in order to have a good and seamless jointing of the stones. The salt concretion was removed by means of a spatula or other tool until a very thin layer of the deposit remained. The cleaning operation had to be stopped at that stage; otherwise the stone

itself would be damaged.

Cleaning of Pustules. Pustules which are sometimes called "stone cancer" result from a combination of biochemical deterioration process. Alveoli resulting from disintegration were sometimes penetrated by algae and mosses. At times also, their surfaces were covered with salt concretions due to the dissolution of the calcareous material inside the structure. Once this happened, one saw only the hardened convex surfaces of the stones, called pustules. If the pustules expanded, they could produce further dilation. Hence pustules ought to be cleaned by opening them and eliminating the microorganism inside manually as well as chemically.

Washing with water followed the whole cleaning operation as well as the final washing itself. In order to avoid any environmental pollution, a chemical deposit tank had been installed to collect the wash water. To ensure that no chemical was left on the stone, the restorers examined the P.H. of the wash water. If the p.H. was still 8 or higher, the cleaning was repeated until the p.H. became neutral. The organic growth and other remains had to be thoroughly washed off to prevent recurrence of the biological deterioration of the stone.

Drying. After all cleaning operations had been conducted, the stones were stacked in a drying chamber with a temperature of 40 C for 2-3 weeks to render them dry before being repaired. Drying was necessary because the adhesives used for repair were synthetic resins.

Repair. After the stones became dry, they were transferred to the repair room. Checking was done here to ascertain which stones needed repairing and what kind of repair ought to be made. Stone repairs comprised the following.

Bonding/Fluing: Stone fragments could be bonded to their mother

block with the help of thermosetting adhesives. If the broken stones had been temporarily bonded with thermoplastic adhesive U-HU during dismantling, they were separated from one another first by means of an Aceton solvent, which also removed the U-HU. The thermosetting adhesives used were:

— **Davis Fuller 614**

Composition: Epoxy resin
Proportion of the resin and its hardener 4:1 (p.b.v.)

Pot life : 1–2 hour (25 C)

Drying time : \pm 4 hours (25 C)

— **Akemi Stein-U Marmorkitt Universal**

Composition : Resine: Polyester
Hardener: Benzoyl peroxyde
Proportion: 100:3 (p.b.v.)

Pot life : 5 minutes (25 C)

Drying time : 40 minutes

The kind of adhesive to be used depended on the volume of the broken stone. Small stone fragments were glued with Akemi which set after 40 minutes, since pressing with a carpenter's press could not be done. Large stone fragments had to be bonded with Davis Fuller because the work took a longer time to perform.

The use of Davis Fuller 614 required a setting time of 3–4 hours. Proper measurement of the proportion of each component of the adhesives during the mixing was imperative in order to obtain the proper mixture. The adhesives were spread out thinly on both broken surfaces; afterwards, the fragments were matched and held together by a carpenter's press during the curing time.



A bas-relief along the lower wall of the Monument.

Dowelling: This method is almost identical to bonding. If the broken stone had technically to carry a heavy load in the structure of the monument, a dowel had to be inserted. On both broken surfaces, a hole was drilled and a brass dowel with rough surfaces (with a diameter of 0.5 cm. to 2 cm. and a length of 8-20 cm.) was inserted in the holes simultaneously as the adhesive mortar was poured. The traditional technique had used iron dowels but experience showed that they rapidly oxidized. That was why they were replaced with brass in the Borobudur Project.

Filling: As a result of stone deterioration, alveoles of the pustules or other holes appeared on the surface of the reliefs. It was necessary to fill up these holes to prevent further deterioration of the stone; they were filled with the same resin mixed with stone powder; at the same time, camouflage work was done on the surface.

Restoring: Restoration of some parts by substituting a new stone for a missing one was done only if necessary. In doing this, technical and archaeological factors were taken into consideration. The new stone had to be petrographically similar to the old one. Restoring was done by placing the new stone in the vacancy left by the missing one. The new stone was bonded with adhesive and carved only with the outlines of the reliefs to preserve the geometric image, to retain their aesthetic value and to insure that the archaeological structure was not violated.

Injection: Fine or very fine cracks often appeared in the stone while the affected part was still attached to the stone block. These were remedied by using a very low viscosity resin, injected into the cracks by means of a syringe. Since this method was difficult to carry out, the cracked portion was usually broken up carefully and the pieces, bonded or dowelled. Another method used which did not include breaking the stone was drilling a hole in the stone cross-

section-wise and filling the bore-hole with resin and a dowel.

Camouflage: Camouflage was done only when the joint of the repaired fragments was not close. Its purpose was to smoothen the joints, to fill the cracks, and to make their texture, lustre and colour similar, or at least not in contrast with the whole surface of the stone. Camouflaging was done only after the resin of the joints had passed its setting time. The technique of camouflage could be described as follows:

The effect of the preventive treatment lasts approximately one year.

The surface is thinly coated with the resin, followed by the application of a mixture of the same resin and stone powder. Colouring agent could be used if necessary. The granulometry and colour of the stone powder should match those of the stone that is to be repaired. The camouflaged surface is then covered with the same stone powder, when the resin mortar is near setting time. After the setting time of the resin passes, the stone powder which has not adhered to the resin is wiped off.

Laying out. This meant a temporary reconstruction of several contiguous stones to facilitate and increase precision of repair works. It was carried out only if necessary.

Preventive Treatment. After cleaning and repair work had been finished, the stones were checked again. Sometimes, a stone was cleaned or repaired anew. Afterwards the stones were treated with Algicide, Herbicide, or Fungicide⁸ to protect them from organic regrowth during the time they were kept in final storage. The method of application varied from

spraying and brushing to injection depending on the condition of the stones.

Continuing Conservation Work

Our experience in the conservation of Borobudur stones showed that the materials and methods used were satisfactory. The stones that had been cleaned with the chemical mixture AC 322 were freed from dirt yet preserved their old appearance, since the patina was not disturbed. The effect of this preventive treatment with pesticides can last approximately one year. It is normal since the monument stones, after rebuilding, are again subject to rain water; without preventive treatment, however, regrowth of micro-organism occurs after one month. Since the chemicals are thoroughly dissolved by the rain during the rainy season, several chemical deposit tanks have been installed at the slopes of the hill beneath Borobudur to prevent environmental pollution. To ensure continued protection of the stones, the conservation staff has scheduled routine maintenance measures comprising manual and chemical treatments. Several chemical preservatives rather than a single product will be alternately used to avoid the possibility of micro-organic immunity.

In general, the growth of micro-organisms on stones since their restoration has been limited only to algae and mosses. The optimal humidity of the surroundings promotes fast growth of these micro-organisms. The watertight layers seem to be functioning well; on the superficial level, however, the stones are still affected by air humidity as well as run-off of the rain water.

As concluded by Mr. Soediman in his paper⁹, continued observations of the results of the conservation will be necessary. The observations will include a study of possible negative effects of the chemicals if used for a long period as stone preservatives. In addition, but much more important, they will also determine alternative pat-

terms for instituting proper long-term preservation maintenance.

The application of Silicone resin as a surface coating to produce water repellency against rain water is still being studied. The high porosity of some stones requires that the study be done. It is necessary to ascertain that silicone resin will not produce any harmful effects, such as detachment, on old stones.

The result of the repair using thermosetting resins is quite good because they possess good adhesion and mechanical properties. In addition, they are also resistant to changes caused by the environment. The thermosetting resins are also viscous enough not to penetrate into the pores of stone. This permits re-breaking of fragments if necessary making the repairing process still reversible.

Note

- 1 This was introduced by the Working Group of ICOM — ICOMOS — ICCROM during its meeting in Bologna, October 1971.

(See G. Torraca, "Treatment of Stone in Monuments: A Review of Principles and Processes", in *The Conservation of Stone I*. Proceeding of the International Symposium, Bologna, June 19-21, 1975, pages 297-316).

2 Protective steps taken to modify destructive factors of the environment on Candi Borobudur include the installation of concrete slabs, filter layers, drainage pipes, and watertight layers. Since these subjects have been elucidated in the paper of Mr. Soediman, they will not be discussed here.

(See *Evaluation of the Recent Restoration of Candi Borobudur*, chapters 2 and 3).

3 G. Torraca, *ibid*.

4 See also Mr. Soediman, *Evaluation of the Recent Restoration of Candi Borobudur*, page 3.

5 It is necessary to note that Borobudur stones are volcanic rock of andesite type. Their porosity varies from 21 to 51%, and their compressive strength

varies from 5-7 according to Mohs scale.

6 A list of materials tested for conservation appears next page.

7 AC 322 was composed of:
 Ammonium Bicarbonate 30 gr
 Sodium Bicarbonate 50 gr
 Carboxymethyl Cellulose 50 gr
 Disodium salt of Ethylene Diamine Tetra Acetic 25 gr
 Disinfectant 3 ml
 Water necessary to reach the volume required 1 litre

8 The chemicals used for preventive treatment are:
 algicide : Proven
 fungicide : Hyamine
 : Quat
 Dimanin A
 herbicide : Hyvar X

The concentration used varied from 1 to 3%, according to the biological population. Their chemical compositions can be seen below

9 691.421.666.71.
 See also Mr. Soediman's paper, chapter 5.

LIST OF CHEMICALS TESTED FOR CLEANING AND PREVENTIVE TREATMENT OF BOROBUDUR STONES

No.	Commercial Name	Type	Basic Composition	No.	Commercial Name	Type	Basic Composition
1.	Benzalkon	Algicide-fungicide	Ankyl dimethyl benzyl ammonium chloride	10.	Noranium	Algicide	Alkyl dimethyl benzyl ammonium chloride
2.	Curitan	Fungicide	Dequadin (Iodine lauryl guanidine acetate)	11.	Preventol O Extra	Fungicide-bactericide	Orthophenyl phenolate
3.	Formaline	Bactericide-fungicide	Formaldehyde	12.	Preventol O.N.	Fungicide-bactericide	Sodium orthophenyl phenolate
4.	Hyvar XP	Herbicide	5 bromo-3 sec. butyl -6-methyl uroci (bromacil)	13.	Preventol P.N.	Fungicide-bactericide	Sodium pentachoro-phenolate
5.	Hyvar XL	Herbicide	Lithium salt of Bromacil	14.	Proven	Algicide	Aryl alkyl trimethyl ammonium chloride and sulfur disphenyl halogen
6.	Iosan	Herbicide	Iodophor formulated with phosphoric acid	15.	Quat	Fungicide	Alkyl dimethyl benzyl ammonium chloride
7.	Karmex	Herbicide	3-(3,4-dichlorophenyl)-1,1-dimethyl uracil	16.	S 66		**
8.	Muslick	Herbicide-fungicide	**	17.	Tordon	Herbicide	4-amino-3,5,6-trichloropicolinic acid and 2,4-dichlorophenoxy acetic acid
9.	Nabasan	Herbicide-fungicide	Disodium ethylene bis dithiocarbonate metallic sulfates				

No.	Commercial Name	Type	Basic Composition	No.	Commercial Name	Type	Basic Composition
18.	Vancide 26	Bactericide-fungicide	Lauryl Pyridium 5 chloro-2 mercapto benzothiazole	22.	Ac 322	Cleaning agent	(See text)
19.	Vancide 26 EC	Bactericide-fungicide	Lauryl Pyridium 5 chloro-2 mercapto benzothiazole	23.	Hyamine	Bactericide-fungicide	Dodecyl tetradecyl hexadecyl dimethyl benzyl ammonium choride
20.	Vancide 51	Bactericide	Sodium dimethyl dithiocarbamate and Sodium 2 mercapto benzothiazole	24.	Dimanin A	Bactericide-algicide	Quartenary compound
21.	Sodium Hydro-oxide	Alkaline	Na OH	25.	Direx	Herbicide	Diuron

**The composition is not known.

LIST OF SYNTHETIC RESINS TESTED FOR REPAIR OF BOROBUDUR STONES

No.	Commercial Name	Type	Ratio of the resin and hardener	No.	Commercial Name	Type	Ratio of th resin and hardener
1.	Akemi Normal	Polyester resin	100 : 3 pbw	7.	Araldit GY 257	Epoxy resin	100 : 18 pbw
2.	Akemi Extra	Polyester resin	100 : 3 pbw	8.	Epasfill PT 521 SL	Epoxy resin	3 : 1 pbv
3.	Akemi Universal	Polyester resin	100 : 3 pbw	9.	Davis Fuller 614	Epoxy resin	4 : 1 pbv
4.	Sinmast P 203	Epoxy resin	3 : 1 pbv	10.	Davis Fuller 609	Epoxy resin	1 : 1 pbv
5.	Araldit AW 106	Epoxy resin	100 : 80 pbw	11.	Instant Resiweld	Epoxy resin	1 : 1 pbv
6.	Araldit XB 2697	Epoxy resin	100 : 33 pbw	12.	Durox 628	Epoxy resin	147 : 53 pbw

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