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इमारतों में पत्थर का रखरखाव और संरक्षण — रीति संहिता

(पहला पुनरीक्षण)

Maintenance and Preservation of Stone in Buildings — Code of Practice

(First Revision)

ICS 91.100.15

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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Stones Sectional Committee, CED 06

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Stone Sectional Committee had been approved by the Civil Engineering Division Council.

The durability of stones depends mainly upon its physical structure and chemical composition. The deterioration takes place when their inherent properties are changed by the action of various unavoidable external agencies. It is always, therefore, desirable to use a good durable stone in the very first instance.

This standard has been formulated to enumerate those principal factors which cause decay of stone in buildings and to suggest preventive measures for their least decay. The preventive measures included are based on the practice being followed in this country and are applicable to particularly porous stones, such as sedimentary rocks, and which are not plastered.

This standard was first published in 1977 and this revision has been taken up in the light of the recent innovations and practices in the industry.

In preparation of the current revision, reference has been made to the following publications:

ASTM C1515-20 'Standard guide for cleaning of exterior dimension stone, vertical and horizontal surfaces, new or existing'.

ICOMOS-ISCS 'Illustrated glossary on stone deterioration patterns', ICOMOS International Scientific Committee for Stone (ISCS), XV, September 2008.

Significant modifications in this revision are:

a) It has been clarified that this standard is applicable only to regular buildings and not for heritage buildings;
b) The list of common agents of deterioration of stones have been revised;
c) A separate section on terminology has been added to explain the various technical terms in the standard;
d) A separate section has been added on the assessment of the structure; and
e) The section on maintenance of stones have been elaborated.

This standard contributes to the United Nations Sustainable Development Goal 11 'Sustainable cities and communities' towards strengthening the efforts to protect and safeguard the world's cultural and natural heritage.

The composition of the Committee responsible for formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

MAINTENANCE AND PRESERVATION OF STONE IN BUILDINGS — CODE OF PRACTICE

(First Revision)

1 SCOPE

1.1 This standard lays down the practice for maintenance and preservation of stones in buildings. It is noted that the provisions of this code are applicable to regular buildings, whereas heritage structures and buildings of historical importance will require a more systematic and careful approach adopting scientific investigations to characterize the existing surface and identifying the root cause of material distress, and in selection of the maintenance or preservation technique that does not compromise the historical value of the surface and building.

1.2 This standard lays down the recommendations for maintenance and preservation of stones in buildings. All of the materials, procedures, and principles are suitable for restoration of historic and non-historic structures unless mentioned specifically.

1.3 Preservation methods are the same as preventive maintenance.

1.4 This standard does not address repair or restoration of the stones, although some of the procedures may be suitable for them.

2 GENERAL

Deterioration can generally be caused by atmospheric agents, improper repairs, incompatible inclusions and neglect; which can cause physical and chemical changes in buildings stones. For maintenance and preservation of stones in buildings it is therefore desirable to know the agencies which deteriorate the stones in buildings. The most common agents of deterioration are discussed in 4.

3 TERMINOLOGY

3.1 Binding Mortar — Binding mortars refer to building materials such as mud mortars, lime mortars or cement mortars or a combination of these, which are used as bonding agents between stone units in stone masonry.

3.2 Consolidant — Consolidants are low viscous chemicals that can penetrate the stone and improve its mechanical properties in addition to acting as a water proofing film over the stone surface.

3.3 Efflorescence — Formation of loose, whitish, powdery crystals made of soluble salt crystals (such as sodium chloride or magnesium sulphate) on the surface of stone. Due to the evaporation of salts in solution within the porous structure of stone, is termed as efflorescence.

3.4 Exfoliation — Exfoliation is a type of detachment or delamination of multiple thin layers parallel to the stone surface, typically occurring in sedimentary and metamorphic rocks.

3.5 Powdering — Powdering is a type of degradation of stone by granular disintegration, typically seen in fine grained varieties of stone, resulting in white powdery patches.

3.6 Structural Instability — Structural instability is caused by the excessive degradation of building stone. It can lead to serious reduction of cross-sectional area of the stone element and to its structural failure.

3.7 Subflorescence — Crystallization of salts within the porous structure of the stone is referred to as subflorescence, as against efflorescence where the crystallization occurs on the surface of the stone.

3.8 Sugaring — Sugaring is a type of degradation of stone by granular disintegration, typically occurring in white crystalline marble.

3.9 Swelling — Swelling is a degradation caused by alternate swelling and shrinking of clay bearing stones due to wetting and drying cycles.

4 AGENTS OF DETERIORATION

4.1 Rain

The stone may be subjected to alternate wetting and drying due to rain and sun, causing temperature stress and weathering. Rainwater also may contain different gases and acids that disintegrate stone. Continuous exposure to moisture can cause surface loss by powdering, sugaring, exfoliation, swelling of clay bearing layers in stones such as sandstones, etc, which can later manifest into deterioration of stone anchorage or structural instability.

4.2 Salts

Exposure to various salts along with dry-wet cycling causes salt crystallization in stones which manifests as efflorescence and sub-florescence depending on the rate of evaporation. The sub-florescence shall damage the structure of the material while the efflorescence may not. The extent of damage depends on core structure of the stone, temperature, humidity, nature of salt, and tensile strength of the material. Damages may initiate as fissures, and progress as crack propagation, progressive loss of mass, and spalling. Stones with pore sizes between 1 µm and 0.1 µm are more prone to salt crystallization damage.

4.3 Freeze-Thaw

In cold places, dry-wet cycling causes the moisture inside the pores to freeze and expand, causing disruption to the material. Cracks, loss of material and spalling are the forms of damages that shall occur.

4.4 Temperature Stresses

At places where the temperature of atmosphere varies considerably, the stones are subjected to alternate heating and cooling due to variation in the ambient temperature. At such places, stresses are induced in the stone which may lead to it's disintegration or cracking.

NOTE — In thinner walls of single stone, since the thermal gradient is not significant, the effect of temperature variation will not be significant.

4.5 Atmospheric Impurities

Atmosphere polluted with acidic gases and smoke may damage stones containing carbonates such as limestones, marbles, calcareous sandstones, etc. Damages due to reactions with the impurities are generally manifested in the form of color changes, appearance of blemishes, and surface powdering of stones.

4.6 Deterioration in Binding Material

Deteriorated mortar or cracks in mortar or joint failures may allow water movement into the wall. Sometimes, the nature of certain binding material can affect the stones adversely, especially if the mortar is denser or less porous than the stones. The compatibility of the physical, mechanical, and chemical properties of the stone and the binding material is of crucial importance in the deterioration mechanisms.

4.7 Movement of Chemicals

If limestone and sandstone are laid close to each other in a structure, the chemicals formed by the reaction of the atmospheric gases with the limestone may enter the sandstone and cause its disintegration.

4.8 Vegetation

Biological or plant growth into the joints between the stones may create cracks, and further entry and movement of water into the cracks may lead to damage progression.

4.9 Damage Due to Metallic Additions

Application of fixtures in iron or other metals over stones causing rusting can be prevented by providing suitable anti-corrosive coating to these fixtures before the application.

4.10 Damage Due to Improper Repairs

Usage of incompatible binders (for example, use of cement-based binder over original lime binder) with stones or unmatching stone replacements can cause bonding and compatibility issues, especially because of obstruction of air and water vapour during transport.

5 ASSESSMENT PROCEDURES

5.1 A walk-around visual survey with a camera would be required as the basis of initial inspection in order to document deterioration in the structure.

5.2 The procedure to be followed before any course of action is:

a) To identify and document defects;

b) To note and measure the extent of defects/patterns/concentration of distress;

c) To postulate the likely causes; and

d) To select and perform necessary maintenance/repair.

5.3 Further, it is important to identify and document any past interventions made to the structure as well.

5.4 When necessary, appropriate field or laboratory testing, or both, is normally included with the condition survey to verify the nature of existing materials and the extent of the work needed to restore the building component to the desired condition.

6 PRESERVATION AND MAINTENANCE METHODS

6.1 Cleaning

6.2 Regular cleaning is critical to the long-term durability of natural stone facades, as well as their appearance. Cleaning methods that do not damage the stone have to be selected. Cleaning methods and materials shall first be tested, from the least to the most aggressive, to determine the mildest treatment that provides satisfactory results. Prior to implementing a building-wide cleaning technique, test areas shall be cleaned using the proposed methods. The areas shall be evaluated for a minimum period of six weeks to assess the results. Improper selection of cleaning chemicals and procedures may produce unsightly and irreversible damage to the appearance, and potentially the structural integrity, of the stone facade component.

6.2.1 *Cleaning by Abrasives*

Cleaning by mechanical abrasive is a specialized method used to eliminate surface soiling from exterior stone masonry and stone cladding. Abrasive cleaning shall be done carefully. Low pressure gentle abrasive systems (less than 2.0 kg per cm^2) with small diameter and low mass abrasives shall be preferred.

Various abrasive media like crushed glass, walnut shells, dry ice, plastic, blast furnace slag, aluminum oxide, and sand may be used. Sometimes, abrasive media can be embedded in sponge particles to control dust and to ensure an even application. Abrasive media can be reused multiple times, but their effectiveness diminishes with each use, and excessive recycling may lead to uneven cleaning results.

For historic stone construction, special care may be taken during the abrasive cleaning process. This method proves most effective in removing atmospheric deposits, efflorescence, and alteration crusts that form due to reaction with atmospheric pollutants bonding to the stone.

6.2.2 *Cleaning by Poulticing*

Poulticing is effective for removal of deep-seated, time-set grime. The technique is suitable for honed or textured stone, stones with intricate carvings, moldings, and other detailing which are difficult to scrub. The holding medium for a poultice can be clays, fuller's earth, talc, cellulose, diatomaceous earth, baking soda, and even flour. This is highly effective with large porosity stones (lime stones).

6.2.3 *Cleaning by Water Soak Method*

Water soaking, also known as water misting, is a widely favoured method for the gentle removal of surface soiling from exterior stone masonry and stone cladding. This technique involves the utilization of very low-pressure water, artfully misted onto the surfaces of exterior stone masonry walls and cladding. This method is suitable for historic as well as non-historic structures and exhibits exceptional effectiveness in removing atmospheric deposits and bioproducts resulting from exposure to acid rain. It is especially suited for limestone and marble substrates, as it delicately lifts away unsightly residues.

6.2.4 *Treatment of Organic Stains by Oxidizing Approach*

Most organic stains, which are carbon-oxygen based, necessitate an oxidizing agent treatment for effective removal. Among the effective options are hydrogen peroxide and commercially available chlorine bleach treatments and poultices. A hair-bleaching solution containing hydrogen peroxide (H_2O_2) as well as chlorine bleaches found in strengths commonly sold for laundry and household use, can be employed for this purpose.

6.3 Preventing Damage to Marble and Limestone

When dealing with marble or limestone surfaces, poultices containing bleach, acid, or strong alkali solutions shall be strictly avoided. Such substances can lead to lightening of colours and surface etching, risking irreversible damage.

6.4 Addressing Pinkish-Brown Stains

Organic substances such as leaves, bark, bird and animal droppings, and food particles can cause pinkish-brown stains when exposed to moisture. The simple removal of these sources, coupled with natural sun and rain action, typically suffices to eliminate the stains. Similar results can be observed with tobacco stains also.

6.5 Treating Urine Stains on Light-Coloured Stone

For light-coloured stone surfaces marred by urine stains, rinsing and exposure to sunlight can often yield effective results. Alternatively, a strong chlorine-bleach poultice or sprinkling with a chlorine-bleaching powdered cleanser can be applied, followed by dampening and allowing it to dry before washing with clean water.

6.6 Eliminating Fire and Smoke Stains

Stains resulting from burning wood or paper, known as fire and smoke stains, can be successfully removed using a commercial fireplace cleaner or a through washing of the affected surface with a solution of caustic soda (sodium hydroxide, NaOH).

6.7 Cautionary Measures with Caustic Soda

Caustic soda, or sodium hydroxide (NaOH), is a potent substance used for stain removal. However, it is highly corrosive and can cause severe burns. Extreme care shall be taken to protect the skin, eyes, and clothing during its handling.

In case of contact, the affected area shall be promptly rinsed with cool, clean water to mitigate any potential harm.

6.8 Chemical Treatment for Metallic Stains

Metallic stains on stone surfaces necessitate precise chemical treatment involving reduction agents capable of attacking the metallic salts, converting them into soluble and colorless forms that can be easily rinsed away or removed with poultices.

6.9 Iron (Ferrous or Ferric) Stains

Iron stains appear reddish-brown, resembling rust, and are usually caused by moisture interacting with adjacent or embedded iron or steel.

Addressing the underlying cause is vital before attempting stain removal. Accessible ferrous items shall be cleaned and painted to prevent over splash and run-off onto the stone. If possible, eliminating sources of moisture can prevent further oxidation and staining.

Superficial, fresh stains often respond well to vigorous scrubbing, while seated stains may require the application of a commercial rust remover following the manufacturer's instructions. For stubborn stains, combining abrasion with a scouring powder and a second application of the rust remover may prove effective.

Deeply seated, rusty stains resulting from prolonged neglect or embedded metal (anchors, ties, etc) may pose significant challenges and may not be removable by any means.

6.10 Copper and Bronze (Cuprous and Cupric) Stains

Copper and bronze stains manifest as green or muddy-brown colorations and typically arise from the interaction of moisture with nearby or embedded bronze, copper, and brass items.

Prior to attempting stain removal, addressing the root cause is essential. Cleaning attached or nearby metal items and applying a quick-drying, clear coating such as varnish, shellac, or a suitable plastic spray-on or brush-on coating can help protect the surfaces. Removing sources of moisture can prevent further oxidation of cuprous metal. When the stain originates from embedded anchors, ties, or other devices, cutting off the moisture supply becomes the only viable remedy, as coating is impractical.

A poultice consisting of a thick paste made from materials like kaolin, fuller's earth, ammonia, or sal ammoniac can be applied to treat the stains effectively. Thoroughly rinsing the area after removal is crucial.

6.11 Lead Stains

Lead stains appear as yellow or orange colorations and may be distant from the source. Treating these stains can be particularly challenging, as lead is relatively unreactive to chemicals. Removing the lead source, if feasible, may allow natural weathering to gradually eliminate the stains.

6.12 Ink Stains

Inks often contain metallic salts, requiring similar treatment methods to those recommended for iron stains.

Non-metallic ink stains can frequently be removed using a poultice or white blotter soaked with household ammonia, followed by thorough rinsing with clean water. For any residual discoloration, a bleaching poultice may be necessary.

6.13 Surface Coatings

Since the principal factors in the decay of stone are the action of atmospheric agencies, the preventive measures shall be aimed at denying access for these destructive agents to the stone. Accordingly, preservatives may be used for filling the pores of the stone, providing a coating to the surface of the stone to prevent the ingress of moisture, and as a reactant which may combine with the stone to form a hard and durable surface.

6.13.1 *General Coatings*

Coatings are applied to the surface, after expelling the moisture from the surface of the stone by sun-drying. The coatings shall be applied before sunset.

6.13.1.1 Coal tar, bitumen, colorless paraffin oil, linseed oil either mixed or unmixed with paint may be used as a coating. Since these interfere with the appearance of the stone, it is not recommended for historical structures. But these coatings may also seal the surface and act as a water-proof layer; which may block the breathability of porous materials. Linseed oil may also undergo biological degradation with time.

6.13.1.2 A solution of silicate of potash or soda which hardens the surface of the stone may be used as a coating.

6.13.1.3 Epoxy resins are not considered as an efficient coating because of the stiffness and yellowing property.

6.13.1.4 These treatments can be applied either by brushing, dipping, or spraying.

6.13.2 *Water Repellents*

Water repellents are preservatives applied on the stone surface without causing any chemical action. They provide a water repellent film on the surface of the stones thus stopping the water from penetrating into the stone but permitting the passage of water vapour through the stone surface. This ensures breathability to the structures, especially the heritage structures made of porous stones.

Water repellants may be acrylic, or silicone based resins in organic solvents; or even water-based products formulated from silanes, siloxanes and other alkoxysilanes. The latter ones can penetrate slightly below the surface and adhere well in addition to forming a film over the substrate. Polyvinyl acetate and polymethyl methacrylate may also used.

6.13.3 *Consolidative Treatments*

Consolidants are low viscous chemicals that penetrate the stone to restore cohesion within the stone and to improve its mechanical properties, along with acting as a water proofing film over the stone surface. The common consolidative treatments can be lime based (hydroxide solutions in lime water), polymeric, silicate based (ethyl silicates, tetraethyl orthosilicate (TEOS), alkaline silicates, fluorosilicates, etc), phosphates, diammonium hydroxy phosphate, barium hydroxide, and magnesium flurosilicate.

In the case of porous stones where improving cohesion between the particles is not a requirement, a consolidative treatment that does not reduce the breathability or block the pore connectivity for vapor transmission has to be selected.

6.13.4 *Biocides*

The moist conditions in tropical climates may promote the growth of biofilm and plants in the presence of water/moisture. In cultural heritage buildings, biocides may be used to stop or reduce the spread of microorganisms. Biocides can be organic or inorganic. Inorganic biocides are long lasting, while organic biocides do not last long as the microbes develop resistance against them quickly.

Biocides can be oxidizing, or non-oxidizing based on their mode of action. Common oxidizing biocides suitable are hydrogen peroxide, bromine, chlorine, and ozone. The most commonly used non-oxidizing biocides are quaternary ammonium compound, acrolein, and aldehyde di-amines and amines.

ANNEX A

(*Foreword*)

COMMITTEE COMPOSITION

Stone Sectional Committee, CED 06

Organization	*Representative(s)*
Indian Institute of Technology Delhi, New Delhi	DR SHASHANK BISHNOI (***Chairperson***)
AIMIL Limited, New Delhi	SHRI ROHITASH BARUA
Central Public Works Department, New Delhi	SHRI K. P. SINGH SHRI PRASHANT SINGH (*Alternate*)
Central Soil and Materials Research Station, New Delhi	SHRI U. S. VIDYARTHI SHRI SACHIN GUPTA (*Alternate*)
Centre for Development of Stones, Jaipur	SHRI MUKUL RASTOGI
Directorate of Geology and Mining, Lucknow	SHRI NAVEEN KUMAR DAS SHRI R. P. SINGH (*Alternate*)
Geological Survey of India, Kolkata	DR DHRUBAJYOTI CHAKRABORTY SHRI RABISANKAR KARMAKAR (*Alternate*)
Indian Institute of Technology Bombay, Mumbai	DR SWATHY MANOHAR
Indian Institute of Technology Delhi, New Delhi	SHRI AMIT KUMAR
Indian Institute of Technology Madras, Chennai	DR MANU SANTHANAM DR ARUN MENON (*Alternate*)
National Council for Cement and Building Materials, Faridabad	DR D. K. PANDA MS RICHA MAZUMDER (*Alternate*)
National Institute of Technology Calicut, Kozhikode	DR A. K. KASTURBA DR JAYACHANDRAN K. (*Alternate*)
School of Planning and Architecture, New Delhi	DR S. K. KHANNA DR SHUVOJIT SARKAR (*Alternate* I) SHRI MEHAR KUMAR KANDIPILLI (*Alternate* II)
Shriram Institute for Industrial Research, Delhi	DR MUKESH GARG DR RAMAN DHYANI (*Alternate*)
Stone Technology Centre, Jaipur	SHRI K. VIKRAM RASTOGI
Tamil Nadu Minerals Limited, Chennai	SHRI HENRY ROBERT SHRI S. THANGAPANDIAN (*Alternate* I) SHRI M. RAMESHBABU (*Alternate* II)
Unique Geocivil Services Private Limited, Surat	SHRI HITESH H. DESAI SHRI NEHAL H. DESAI (*Alternate*)
In Personal Capacity (*6/KA 16 Jawahar Nagar, Jaipur - 302004*)	SHRI PRADEEP AGARWAL
In Personal Capacity (*13-A Ram Nagar Roorkee - 247667*)	DR RAJNI LAKHANI
In Personal Capacity (*Flat 119, Amulya Fortune Apartments, Road No 1, Opp. Union Bank, Madhavapuri Hills, Chandanagar, Hyderabad - 500050*)	SHRI K. SITARAMANANJEYULU

Organization	*Representative(s)*
BIS Directorate General	SHRI DWAIPAYAN BHADRA, SCIENTIST 'E'/DIRECTOR AND HEAD (CIVIL ENGINEERING) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

Member Secretary
SHRIMATI DIVYA S.
SCIENTIST 'D'/JOINT DIRECTOR
(CIVIL ENGINEERING), BIS

Working Group for the Revision of IS 8759

Organization	*Representative(s)*
Indian Institute of Technology Madras, Chennai	DR ARUN MENON (***Convener***)
Indian Institute of Technology Bombay, Mumbai	DR SWATHY MANOHAR

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices: *Telephones*

Central : 601/A, Konnectus Tower -1, 6th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002 — 2323 7617

Eastern : 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091 — 2367 0012, 2320 9474

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019 — 265 9930

Southern : C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113 — 2254 1442, 2254 1216

Western : 5th Floor/MTNL CETTM Technology Street, Hiranandani Gardens, Powai, Mumbai - 400076 — 25700030, 25702715

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