KENYA STANDARD **DKS 3015-9:2024**

ICS XXXX

First Edition

Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 9: General principles for the use of products and systems

TECHNICAL COMMITTEE REPRESENTATION

The following organizations were represented on the Technical Committee:

Ministry of Roads and Transport – Material Testing and Research Directorate

Kenya National Highways Authority

Surtech Limited

Bamburi Special Products Limited(Bamburi Cement PLC)

Kenya Builders and Concrete Company Limited

Kenya Bureau of Standards — Secretariat

REVISION OF KENYA STANDARDS

In order to keep abreast of progress in industry, Kenya Standards shall be regularly reviewed. Suggestions for improvements to published standards, addressed to the Managing Director, Kenya Bureau of Standards, are welcome.

KENYA STANDARD

DKS 3015-9:2024

ICS XXXX

First Edition

Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 9: General principles for the use of products and systems

Kenya Bureau of Standards, Popo Road, Off Mombasa Road,
P.O. Box 54974 - 00200, Nairobi, Kenya

+254 020 6948000, + 254 722202137, + 254 734600471

info@kebs.org

@KEBS_ke

kenya bureau of standards (kebs)

Foreword

This Kenya Standard was prepared by the Concrete Technical Committee under the guidance of the Standards Projects Committee, and it is in accordance with the procedures of the Kenya Bureau of Standards.

Kenya Bureau of Standards (KEBS) has established Technical Committees (TCs) mandated to develop Kenya Standards (KS). The Committees are composed of representatives from the public and private sector organizations in Kenya.

Kenya Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft Kenya Standards are circulated to stakeholders through the KEBS website and notifications to World Trade Organization (WTO). The comments received are discussed and incorporated before finalization of the standards, in accordance with the Procedures for Development of Kenya Standards.

Kenya Standards are subject to review, to keep pace with technological advances. Users of the Kenya Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

DKS 3015 consists of the following parts, under the general title *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity*:

— *Part 1: Definitions*

— *Part 2: Surface protection systems for concrete*

— *Part 3: Structural and non-structural repair.*

— *Part 4: Structural bonding*

— *Part 5: Concrete injection*

— *Part 6: Anchoring of reinforcing steel bars.*

— *Part 7: Reinforcement corrosion protection.*

— *Part 8: Quality control and assessment and verification of the constancy of performance (AVCP).*

— *Part 9: General principles for the use of products and systems.*

— *Part 10: Site application of products and systems and quality control of the works.*

During the preparation of this standard, reference was made to the following document (s):

EN 1504:9-2011, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 9: General principles for the use of products and systems.*

Acknowledgement is hereby made for the assistance derived from this source.

Contents

Page

Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 9: General principles for the use of products and systems

1 Scope

This Kenya Standard sets out basic considerations for specification of protection and repair of reinforcement and unreinforced concrete structures including pavements, runways, floor slabs and pre-stressed structures using products and systems specified in this series of standards.

It shall also cover atmospherically exposed, buried and submerged structure.

This standard includes:

1) The need for inspection, testing and assessment before and after repair;

2) Protection from causes of defects and their repair in concrete structures. Causes of such defects may include:

   a. Mechanical actions e.g. impact, overloading, movements caused by settlement, bias vibrations and seismic actions;
   b. Chemical and biological actions from environments e.g. sulphate attack, alkali aggregate reaction;
   c. Physical actions e.g. freeze-thaw action, thermal cracking, moisture movement, salt crystallization and erosion;
   d. Fire damage;
   e. Reinforcement corrosion resulting form;
      i. Physical loss of the protective concrete cover;
      ii. Chemical loss of alkalinity in the protective concrete cover as a result of reaction with atmospheric carbon dioxide (carbonation);
      iii. Chloride or other chemical) contamination of the concrete;
      iv. Stray electrical currents conducted or induced in the reinforcement from neighbouring electrical insulation.

3. Repair of defects caused by inadequate design, specification or construction or use of unsuitable construction materials;

4. Providing the required structural capacity by;
   a. Replacement or additional of embedded or external reinforcement;
   b. Filling of cracks and voids within or between elements to ensure structural continuity;
   c. Replacement or addition of concrete or whole elements.

5. Waterproofing as an integral part of protection and repair.

6. Principles and methods of protection and repair as listed in table 1.

The site application of this standard are specified in part 10 of this standard series.

2 Normative references

The following referenced documents referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

KS EAS 131-1:2008, *Concrete-Specification, performance, production and conformity.*

ISO 12696:2022, *Cathodic protection of steel in concrete.*

DKS 3015-1:2024, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 1: Definitions.*

EN 1504:2-2004, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 2: Surface protection systems for concrete.*

EN 1504:3-2006, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 3: Structural and non-structural repair.*

EN 1504:4-2005, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 4: Structural bonding.*

EN 1504:5-2014, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 5: Concrete injection.*

EN 1504:6-2007, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 6: Anchoring of reinforcing steel bars.*

EN 1504:7-2007, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 7: Reinforcement corrosion protection.*

EN 1504:8-2020, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 8: Quality control and assessment and verification of the constancy of performance (AVCP).*

EN 1504:10-2019, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 10: Site application of products and systems and quality control of the works.*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the first part of this series of standards and the following apply.

3.1
Defect
Unacceptable condition that may be in-built or the result of deterioration or damage.

3.2
Design life
Intended useful period of service under expected conditions of use of the concrete structure

3.3
Maintenance
Recurrent or continuous measures that provide repair and/or protection

3.4
Passivity

State in which steel in concrete does not spontaneously corrode due to a protective oxide film

3.5
Protection
Measure that is intended to prevent or reduce the development of defects in the surface

3.6
Repair
Measure that is intended to rectify defects in the structure

3.7
Service life
Period over which the intended performance is achieved

3.8
Substrate
Surface on which a protection or repair material is to be applied

3.9
Stray currents
Currents flowing through steel embedded in the concrete other than the intended circuits

4 Minimum requirements before protection and repair

4.1 General

This clause specifies the procedures that shall be undertaken to assess the current conditions of a concrete structure before protection and repair.

General guidance is given in Annex A

4.2 Health and Safety

The risks to health and safety from falling debris or local failure due to removing materials and the effect of deterioration upon the mechanically stability of the concrete structure shall be assessed.

Where the concrete structure is considered to be unsafe, appropriate action shall be specified to make it safe before other protection or repair work is undertaken, taking into account any addition risks that may arise from the repair work itself. Such action may include local protection or repairs, the installation of support or other temporary works, or partial or even complete demolition.

4.3 Assessment of Defects and their Causes

An assessment shall be made of the defects in the concrete structure, their causes, and of the ability of the concrete structure to perform its function.

The process of assessment of the structure shall include but not limited to the following:

a. The visible condition of the existing concrete structure;
b. Testing to determine the condition of the concrete and reinforcing steel;
c. The original design approach;
d. The environment, including exposure to containment;
e. The history of the concrete structure, including environmental exposure;
f. The condition of use, (e.g. Loading or other actions)
g. Requirements for future use.

The nature and causes of defects, including combinations of causes, shall be identified and recorded. Further guidance on the effect of design and construction errors on the durability of the structure is given in the annex.

The approximately extent and likely rate of increase of defects shall then be assessed. An estimate shall be made of when the member or concrete structure would no longer perform as intended, with no protection or repair measures (other than maintenance of existing systems) applied.

The results of the completed assessment shall be valid at the time that the protection and repair works are designed and carried out. If as a result of passage of time or for any other reason, there are doubts about the validity of the assessment, a new assessment shall be made.

NOTE 1 Stray current can lead to corrosion of reinforcement through changing the electrical charges of reinforcement especially in buried reinforcement.

Figure 1:Common Causes of defects

5 Protection and Repair within a Structure Management Strategy

5.1 General

This clause identifies options and factors to be considered when choosing a strategy for the management of the structure.

5.2 Options

The following structure management options shall be taken into account when deciding the appropriate action to meet the future requirements for the life of the structure:

1. Do nothing for a certain time but monitor;
2. Re-analyse the structural capacity, possibly leading to downgrading in function;
3. Prevent or reduce further deterioration;
4. Strengthen or repair and protect all or part of the concrete structure;
5. Reconstruct or replace all or part of the concrete structure;
6. Demolish all or part of the concrete structure.

5.3 Factors

Factors to be considered when choosing a management strategy include but are not limited to the following categories:

1. Basic:
   a. The intended use and remaining service life of the structure;
   b. The required performance of the structure (i.e. fire resistance and water-tightness)
   c. The likely service life of the protection and repair works;
   d. The required availability of the structure, permissible interruption to its use and opportunities for additional protection, repair and monitoring work;
   e. The comparative whole life cost of the alternative management strategies, including future inspection and maintenance or further repair cycles;
   f. Properties and possible methods of preparation of the existing substrate;
   g. The appearance of the protected and repaired structure.

2. Structural
   a. Actions during and after implementation of the strategy;
   b. Actions how they will be resisted.

3. Health and Safety
   a. The consequences of structural failure;
   b. Health and safety requirements;
   c. The effect on occupiers or users of the structure and on third parties.

4. Environmental
   a. The exposure environment of the structure and whether it can be changed locally;
   b. The need or opportunity to protect part or all of the concrete structure, from weather, pollution, salt spray etc. including protection of the substrate during the repair work.

5.4 Choice of Appropriate Strategy

The choice of strategy for the structure shall be based in the above assessment of the structure, client requirements, and relevant provisions e.g. safety requirements, valid in the place of execution. All protection and repair works undertaken as part of a structure management strategy shall comply with this Standard.

A protection and repair principle(s) shall be chosen according to clause 7:

a. Appropriate to the type, cause or combination of causes and to the extent of the defects;

b. Appropriate to the future service condition.

6 Basis for the Choice of Protection and Repair Principles and Methods

6.1 General

This clause specifics the basic principles which shall be used, separately or in combination, to protect or repair concrete structures.

NOTE: Methods which do not use products and systems covered by other standards of this series are addressed in 7.2.

6.2 Principles and methods of protection and repair

6.2.1 General

The principles of protection and repair are based on chemical, electrochemical or physical principles that can be used to prevent or stabilise the deterioration of concrete or electrochemical corrosion on the steel surface, or to strengthen the concrete structure.

Table 1 contains examples of protection and repair methods which apply the principles. Only methods which comply with the principles shall be selected, taking into account any possible undesirable consequences of applying a particular method or combination of methods under the specific conditions of the individual repair.

Other methods not described in this Kenya Standard may be used if there is documented evidence that they comply with one or more principles.

Specifications for products and systems that may be used to implement a particular method are given in the previous series of this standard standards of this series, as indicated in Table 1.

6.2.2 Principles and methods related to defects in concrete

Principles 1 to 6 in Table 1 cover defects in the concrete or concrete structures that may be caused by the following actions, that may act either singly or in combination:

a. Mechanical e.g. impact, overloading, movement caused by settlement and blast:
b. Chemical and biological e.g. sulphate attack, alkali aggregate reaction:
c. Physical e.g. freeze-thaw action, thermal cracking, moisture movement, salt crystallization and erosion:
d. Fire.

6.2.3 Principles and methods related to defects in reinforcement corrosion

Principle 7 to 11 in Table 1 cover reinforcement corrosion caused by:

a. Physical loss of the protective concrete cover;
b. Chemical loss of alkalinity in the protective cover as a result of reaction with atmospheric carbon dioxide (carbonation);
c. Contamination of the protective concrete cover with corrosive agents (usually chloride ions) which were incorporated in the concrete when it was mixed or which have penetrated into the concrete from the environment:
d. Stray electrical currents conducted or induced in the reinforcement from neighbouring electrical installations.

Where there is existing corrosion of reinforcement or a danger that corrosion will occur in the future, one or more principles of corrosion protection and repair (Principles 7 to 11 in Table 1) shall be selected.

In addition, the concrete itself shall be repaired, where necessary, according to Principles 1 to 6.

Table 1 — Principles and Methods for Protection and Repair of Concrete Structures

Principle	Examples of methods based on the principles	Relevant part of this standard applicable
Principles and methods related to defects in concrete		
1. Protection against ingress	1.1 hydrophobic impregnation	2
	1.2 Impregnation	2
	1.3 Coating	2
	1.4 surface bandaging of cracks	
	1.5 Filling of cracks	5
	1.6 Transferring cracks into joints	
	1.7 Erecting external panels	
	1.8 Applying membranes	
2. Moisture Control	2.1 hydrophobic impregnation	2
	2.2 Impregnation	2
	2.3 Coating	2
	2.4 Erecting external panels	
	2.5 Electrochemical treatment	
3. Concrete restoration	3.1 Hand-applied mortar	3
	3.2 Recasting with concrete or mortar	3
	3.3 Spraying concrete or mortar	3
	3.4 Replacing elements	
4. Structural strengthening	4.1 Adding or replacing embedded or external reinforcing bars	
	4.2 Adding reinforcement anchored in pre-formed or drilled holes	6
	4.3 Bonding plate reinforcement	4
	4.4 Adding mortar or concrete	3,4
	4.5 Injecting cracks, voids or intersections	5
	4.6 Filling cracks, voids or intersections	5
	4.7 Pre-stressing-(post-tensioning)	
5. Increasing physical resistance	5.1 Coating	2
	5.2 Impregnation	2
	5.3 Adding mortar or concrete	3
6. Resistance to chemicals	6.1 Coating	2
	6.2 Impregnation	2
	6.3 Adding mortar or concrete	3
Principles and methods related to reinforcement corrosion		
7. Preserving or restoring passivity	7.1 Increasing cover with additional mortar or concrete	3
	7.2 Replacing contaminated or carbonated concrete	3
	7.3 Electrochemical realkalisation of carbonated concrete	
	7.4 Realkalisation of carbonated concrete by diffusion	
	7.5 Electrochemical chloride extraction	
8. Increasing resistivity	8.1 Hydrophobic impregnation	2
	8.2 Impregnation	2
	8.3 Coating	2
9. Cathodic control	9.1 Limiting oxygen content (at the cathode) by saturation or surface coating	
10. Cathodic protection	10.1Applying an electrical potential	
11. Control of anodic areas	11.1 Active coating of the reinforcement	7
	11.2 Barrier coating of the reinforcement	7
	11.3 Applying corrosion inhibitors in or to the concrete	
NOTE These methods may also be applicable to other principles		

6.2.4 Protection and Repair of Concrete and Reinforcement by Methods not Mentioned in this Kenya Standard

The absence from this Kenya Standard of a specific method, or the application of a method to a new situation, shall not be taken to mean that such a method or application is necessarily unsatisfactory. The application of methods to situations unforeseen in this Kenya Standard or the use of methods which do not have a substantial history of successful performance and are not specified in this Kenya Standard, may be satisfactory in appropriate circumstances.

7 Properties of products and systems required for compliance with the principles of protection and repair

7.1 General

When the appropriate methods have been chosen in accordance with the principles given in Clause 7, the products and systems to be used shall be selected in accordance with the requirements of this series of Kenya Standard as shown in Table 1, or other relevant Kenya Standard.

Descriptions and acceptance values of properties in relation to specific products and systems are specified. Care shall be taken that products and systems do not undergo adverse physical or chemical reactions with each other and with the concrete structures.

Repair products that are part of a system for repair shall not normally be tested individually unless one or more of the repair products are intended to meet particular performance requirements in its own right.

Part 10 of this series of standard gives details of site application requirements. If on-site application conditions cannot reasonably be made to fulfil the application conditions specified for the product or system, alternative products (if any) or alternative repair principles or methods shall be specified to avoid such a conflict.

7.2 Methods which do not make use of specific product and systems

In the case of methods listed in Table 1 which do not make use of specific products and systems conforming to the relevant parts of standards of this series or other relevant Kenya Standards, appropriate values shall be specified for the properties of the selected products or systems

8 Maintenance following completion of protection and repair

Unless otherwise agreed, the following shall be provided:

a. A record of the protection and repair works which have been carried out, including any test results;
b. Instructions on inspection and maintenance to be undertaken during the remaining design life of the repaired part of the concrete structure.

9 Health, safety and the environment

The specification for protection and repair shall comply with the requirements of relevant health and safety, environmental protection and fire regulations.

Where there is a conflict between the properties of specific products or systems and environmental protection or fire regulations, use shall be made of alternative repair principles or methods which avoid such a conflict.

10 Competence of Personnel

This Kenya Standard presupposes that personnel have the necessary skill and adequate equipment and resources to design, specify and execute the work in accordance with the relevant part of standards of this series and the requirements of the project specification.

Annex A
(informative)

Guidance and background information

A.1 Introduction

This Annex defines the principles for protection and repair of concrete structures that have suffered or may suffer damage or deterioration, giving guidance on effective intervention intended to reduce the risk of future significant unplanned deterioration and maintenance. This Annex also gives guidance on the selection of products and systems which are appropriate for the intended use.

A.2 Scope

Some aspects of the scope will require specialised knowledge and structural design. Examples include structural requirements of fire-damaged concrete, assessment and repair of pre-stressed concrete and increasing structural capacity by replacement or addition of embedded or external reinforcement.

The scope does not include non-structural construction materials used in conjunction with concrete, such as floor screeds or render and plaster finishes:

a. The scope of this Annex does not include detailed guidance on inspection, testing and assessment either before or after repair.
b. In well designed and constructed concrete structures, the concrete cover should normally protect reinforcement from corrosion under conditions of normal exposure in natural environments, including marine environments and where de-icing salts are used. With older structures, previous standards may not have been adequate for normal exposure. In particular, inadequate design, specification or construction, or use of unsuitable construction materials, may lead to a poor quality cover concrete, poor compaction and hence reduced durability of reinforced concrete. Other mechanisms may cause premature deterioration, including fire, mechanical actions or chemical attack.
c. For waterproofing of vertical surfaces, vapour-permeable materials are normally used; for waterproofing horizontal surfaces materials that are impervious to water and water vapour are normally used, but this depends on the intended use of the structure.
d. Part 10 of this series of standard covers site application and includes details of methods of protection and repair, including the preparation of the concrete and reinforcement before application of products and systems.

Products and systems may be applied for purposes other than protection and repair, for example solely or mainly to improve appearance, or to modify a concrete structure for a different use.

A.3 Terms and definitions

These include terms that are not in common use in construction and which have a special meaning in this Annex.

A.3.1 Passivity

When reinforcement is surrounded by uncontaminated alkaline concrete, the high alkalinity naturally present leads to the formation of a protective oxide layer on the steel surface, termed passivity. This layer effectively reduces the risk of reinforcement corrosion to an insignificant level, despite the simultaneous presence of water and oxygen.

The protection afforded by the protective oxide layer is lost when the concrete carbonates to the depth of the reinforcement or when aggressive salts are present in sufficient quantities at the depth of the reinforcement. This results in active corrosion in the presence of moisture and oxygen, which may lead to cracking and spalling of the cover.

To prevent loss of passivity, or where passivity has been lost, appropriate products and systems can be used to control corrosion of the steel reinforcement, in line with the principles of this Kenya Standard.

A.3.2 Service life

It is normally expected that a new concrete structure or, following intervention, a protected or repaired concrete structure will achieve its service life without significant unplanned deterioration and maintenance.

A.3.2 Substrate

A substrate would normally require preparation, cleaning and testing prior to the application of products and systems for protection and repair. (Compatibility)

A.4 Minimum requirements before protection and repair

A.4.1 General

A.4 is not a detailed guide to undertaking a structural appraisal or a condition assessment of the concrete structure.

Table A.1 gives an example of the phases of a repair project.

Table A-1 – Phases of a repair project

PROJECT PHASES

INFORMATION ABOUT THE STRUCTURE	PROCESS OF ASSESSMENT	MANAGEMENT STRATEGY	DESIGN OF REPAIR WORK	REPAIR WORK	ACCEPTANCE OF REPAIR WORK
Basic considerations and requirements					
• Condition and history of structure • Documentation • Previous repair and maintenance	• Defects and their classifications and clauses • Safety/structural appraisal before protection and repair	• Options • Principles • Methods • Safety/structural appraisal during protection and repair	• Intended use of products • Requirements: — Substrate — Products — Work • Specifications • Drawings • Safety/structural appraisal during protection and repair	• Choice and use of products, systems, methods and equipment to be used • Tests of quality control • Health and safety	• Acceptance testing • Remedial works • Documentation
Relevant Clauses in this Kenya standard and other parts of this Kenya standard series					
• Clause 4 of this standard	• Clause 4 of this standard	• Clause 5 and 6 of this standard	• Standards of this series • Clause 6,7 and 9 of this standard	• Clause 6,7,9 and 10 of this standard • Part 10 of this series	• Clause 8 of this standard • Part 10 of this series

Before any repair and protection work can start, a data collection exercise needs to be completed to establish the current condition of the structure, the maintenance history and the likely future performance Ideally, this should be undertaken in the context of a structure management strategy, which is discussed in more detail in Clause 5

A.4.2 Health and Safety

The structural assessment of deteriorated structures is governed by national standards, regulations and guidance and is not discussed further. See also A.5.3.2 (Structural factors) and A.5.3.3 (Health and Safety factors) for information on the requirements before, during and after repair and protection works.

Where a risk to third parties exists, all loose and spalled material should be removed as part of the initial survey works.

A.4.3 Assessment of defects and their causes

A.4.3.1 General

These clauses provide background information on the assessment of defects and their causes and does not provide detailed comments on the individual sub-clauses in the normative text.

A.4.3.2 Defects and Causes

Defects in concrete structures can result from inadequate design, specification, supervision, execution, and materials, including:

- Inadequate structural design;
- Inadequate mix design, insufficient compaction, insufficient mixing;
- Insufficient cover;
- Insufficient or defective waterproofing;
- Contamination, poor or reactive aggregates;
- Inadequate curing.

Other defects may become apparent during service, including the effects of:

- Reinforcement corrosion;
- Severe climate, atmospheric pollution, chloride, carbon dioxide, aggressive chemicals;
- Foundation movement, impacted movement joints, overloading;
- Impact damage, expansive forces from fires;
- Erosion, aggressive groundwater, seismic action;
- Stray electric currents.

The common causes of defects in concrete and corrosion of reinforcement are summarised in figure 1.

A.4.3.3 Condition assessment

Prior to repair work commencing, all previous information on the structure should be collated and reviewed.

When defects are observed, additional testing and assessment should be carried out to establish the cause and extent of the defects and to predict future performance.

The condition of the concrete and reinforcement should be established and documented and the data stored in a management system. Prior to repair work commencing, all previous information on the structure should be collated and reviewed.

A typical assessment would include insitu testing for cover to reinforcement and carbonation depth, drilled dust sampling to determine the chloride ion content and profile and the presence of other deleterious substances, and cores for physical, chemical and petrographic analyses. Electrochemical testing of the reinforcement (e.g. by half-cell potential technique) may be required in certain instances where elevated chloride ion contents have been measured and active hidden corrosion may be present.

Generally, corrosion of embedded reinforcement ultimately results in cracking and spalling of the concrete cover. However, it should be kept in mind that active corrosion may occur for a considerable time before cracks appear and also that, under certain conditions, the corrosion may not be expansive and therefore may not result in cracking. This being the case, electrochemical testing should be considered because it is able to detect active corroding reinforcement even though there are no outward visible signs Such hidden damage also needs to be considered in the structure management strategy (see A.5).

The assessment of existing condition and prediction of future performance should preferably include consideration of previous tests made at suitable intervals and information on the history of the concrete structure, for instance construction, use and management (where available).

An assessment is normally carried out as a separate operation before the start of the protection and repair works. Assessments of the structure that are carried out some time before the design of the repair works is considered may not represent the contemporary condition and structural capacity at the time the repair works are designed. In such cases the assessment needs to be updated before the protection and repair works are designed. In all cases, it is essential to assess the full extent and causes of the detects.

A condition assessment may be undertaken in more than one stage. For example, a preliminary stage may be required to provide immediate advice on the safety of the concrete structure and any risk to third parties, with a more detailed assessment undertaken immediately before the works are designed.

The assessment of defects, the prognosis for their further development and the structural assessment should be recorded.

A.4.3.4 Structural Appraisal

As part of the structural appraisal, the properties of the concrete (e.g. compressive strength and elastic modulus) and the reinforcement detailing (e.g. bar size, type, spacing and cover) may need to be verified through testing. Recalculation of the remaining load capacity in the deteriorated state may be needed.

A.4.3.5 Qualification of assessors

Condition assessments and structural appraisals are often carried out in advance of the repair process set out in this Kenya Standard and sometimes before it has been recognised that a problem exists. All assessments should be made by suitably qualified personnel with knowledge of investigation methods, structural design, maintenance, material technology and of the mechanisms which can contribute to the deterioration process of concrete structures. It should be noted that national or local rules for assessors may apply.

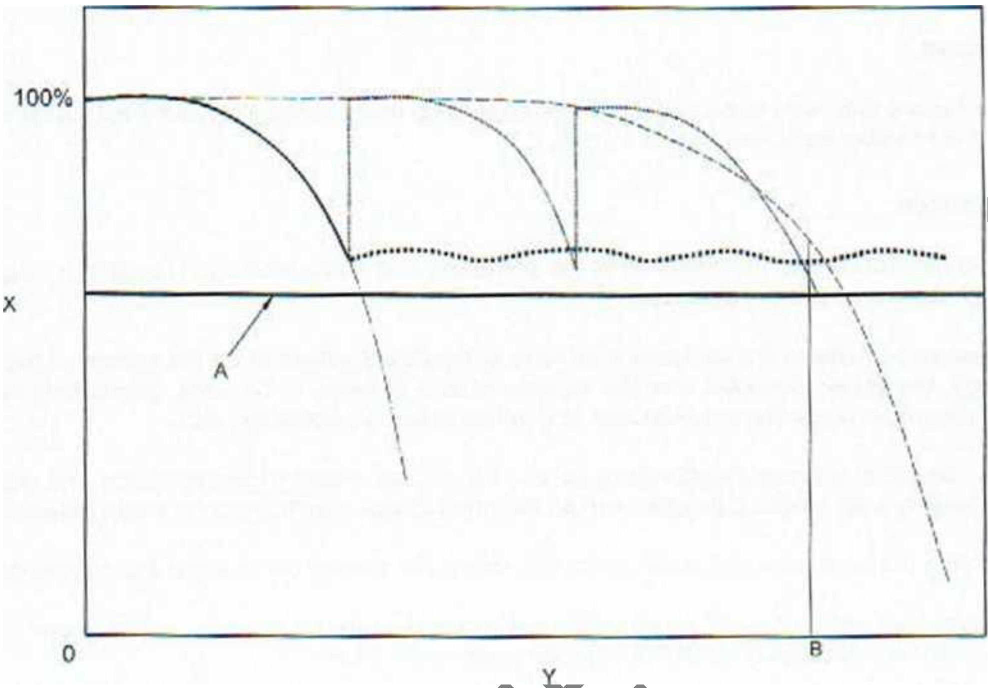
The competence of personnel designing, specifying and executing concrete repair works is set out at A.9.

A.5 Protection and repair within a structure management strategy

A.5.1 General

A structure management strategy is not chosen on technical grounds alone, but also on economic, functional, environmental and other factors, and most importantly the owner’s requirements for the structure.

The design life of the repaired concrete structure is a key consideration in the design of the protection and repair system. Options range from those that can restore the design life of the concrete structure in a comprehensive single operation, to simpler options that may require repeated maintenance or where components of the repair may need to be reapplied (e.g. surface protection systems), as illustrated in Figure A-1 below.



Key

X Asset condition

Y Life of the asset

A Critical condition

B Target life

— — — — — — Ideal life curve

———————— Actual deterioration curve

——— • • —— Projected deterioration

Repair based on:

▪▪▪▪▪▪▪▪▪▪ Restoring to initial state x2

■ | ■ ■ ■ ■ ■ Maintaining current state

Figure A- 1-Typical repair cycles over the life of a deteriorating asset

A.5.2 Options

Maintaining or restoring safety is an essential requirement of a structure management strategy. A range of options may be available to meet this prerequisite. These options should normally be assessed for their efficacy over the remaining life of the structure, termed life cycle costing.

Consideration of the options and their consequences will generally include examination of different aspects, for example initial cost, maintenance costs and the possible need to introduce restrictions on the use of the structure. Each option is likely to have a different level of future deterioration risk.

When choosing options for protection and repair systems, an important consideration is the life to first maintenance of the individual products, as they may not last for the design life of the concrete structure. Factors such as access to the works and the renewal and reparability of protection and repair systems are important considerations.

A.5.3 Factors

Clause 5.3 lists the factors that need to be considered when making an informed judgement on the relative costs and benefits of the possible technical options for repair.

A.5.3.1 General

a. Correct monitoring and maintenance of the protection and repair works will result in a longer service life for both the works and the structure.
b. The nature and use of the structure may have a significant influence on the choice of the management strategy, the repair principles and the equipment and systems to be used, particularly noise and dust generation from preparing the substrate (e.g. office buildings, hospitals, etc.).
c. In the case of premature deterioration, service life can be extended by protection and repair. However, deterioration is an on-going process and an informed choice may have to be made between:
   i. Carrying out protection and repair which will extend the service life to attain the original design life:
   ii. Carrying out protection and repair which will extend the life for a lesser period in the knowledge that there will be additional protection and repair costs in the future.
d. Properties and possible methods of preparation of the existing substrate can have an effect on the final appearance of the protected and repaired structure.

A.5.3.2 Structural Factors

The structural appraisal prior to repair can be extended to predict the effects of the repair works on the structural capacity, both during repair and after the works have been completed.

Particular attention needs to be paid to the volume of concrete and reinforcement that is cut away from loadbearing structural members and the effect this will have on the future structural capacity. An example is the removal of concrete from compression members, altering load paths such that the repairs are effectively not loadbearing. Should this be of structural significance, repair principles should be considered that minimise the breakout and repair and/or utilise propping to relieve dead load during the repair.

A.5.3.3 Health and Safety Factors

a. An important stage in the structure management strategy is to assess the structural consequences from any deterioration and the repair process itself before work begins;
b. Health and safety requirements are given in national regulations and guidelines;
c. The materials and methods used in the selected repair principles will potentially affect operatives as well as occupiers, user or third parties. Examples include: products that contain harmful or malodorous components; creation of noise, dust and vibration, water or airborne debris from preparation processes, or plant movements.

A.5.4 Choice of Appropriate Strategy

The structure management strategy should reflect the client's requirements for the design and service life of the structure and the maintenance and repair options, which given which management strategy should be developed.

The initial causes of the defects need to be identified. Generally, protection and repair will deal successfully with the causes and consequences of defects. In some cases, other issues may be contributing to the deterioration (e.g. blocked drains on bridge decks that lead to chloride contamination of the substructure) and it may be necessary to deal separately with those issues before a successful repair can be carried out. If correction of the cause is not possible (e.g. in a marine environment), the protection and repair must be designed to resist the cause as far as possible.

A.6 Basis for the choice of protection and repair principles and methods

A.6.1 General

Selection of appropriate repair principles is the most important part in the design of the repair project. Several approaches may be possible, with the final selection based on a variety of factors (see A.5.1).

Suitable repair methods should be specified for all chosen principles. Where possible, the specification should include the appropriate performance requirements for products and systems for the intended use. Producers may need to be consulted to verify that their products or systems fulfil the intended requirements.

Products and systems for the intended use should be selected taking into account the condition of the substrate and the assessment of defects and their causes as detailed in 4.3 of this Kenya Standard.

A.6.2 Principles and methods of protection and repair

Several protection and repair methods may be chosen in combination. Care needs to be taken to consider the possible adverse effects of the chosen methods and the consequences of interactions between them.

Examples of possible adverse effects include:

a. Hydrophobic impregnation system used to reduce the moisture content of concrete, which may increase the rate of carbonation;
b. Surface coating, which may entrap moisture, leading to a breakdown in adhesion or reduced frost resistance;
c. Post-tensioning. Which can cause tensile stresses in the structure;
d. Electrochemical methods, which may cause embrittlement of susceptible prestressing steel, alkali aggregate reaction with susceptible aggregates, a decrease in frost resistance due to increased moisture contents, or, if under water, corrosion in adjacent structures or vessels.

Products and systems should be compatible with each other and with the original concrete structure.

Where there is a history or risk of reinforcement corrosion, Principle 7 to 11 in Table 1 should be considered in addition to Principle 1 to 6, because the expansive effects of ongoing reinforcement corrosion may damage concrete in the future if left unchecked.

A.6.2.1 Principles and methods related to defects in concrete

A.6.2.1.1 General

This clause provides background information on repair. Principles 1 to 6 in Table 1 does not provide detailed comments on the individual sub-clauses in the normative text.

A.6.2.1.2 Principle 1- Protection against Ingress

Protection against ingress includes measures to reduce the porosity or permeability of the concrete surface. This is achieved by treating the concrete surface (e.g. using a surface protection system) or sealing cracks (e.g. injection of cracks, or by bandaging or filling the surface).

Normal structural cracks have widths that are within the limits defined in KS EN 1992-1-1, which open and close in response to loads under the control of the reinforcement in concrete. Overload or under-design of a structure may result in structural cracks that exceed the limits defined in KS EN 1992-1 -1.

Non-structural cracks may form in the concrete for a number of reasons, e.g. plastic shrinkage or settlement, heat of hydration, thermal contraction and these may be much wider than structural cracks and may open and close in response to both structural loads and environmental effects such as temperature changes.

Cracks of any width may cause deterioration and the consequences should be considered. Where there is a danger that corrosive contaminants will penetrate the concrete at cracks, consideration should be given to protecting cracks that are currently free from contamination by filling them in accordance with method 1.4 in Table 1.

Once the causes, ranges of movements and effects have been established, including whether the crack is live (e.g. opening and closing in response to loads or thermal effects) or dead, then options for repair can be selected from methods 1.1 to 1.8 in Table 1. Some surface protection systems specified in another part of standard of this series are suitable for application over live normal structural cracks but few will bridge wide, non-structural cracks, which may need to be sealed by other methods.

Some cracks in hardened concrete form as a result of reinforcement corrosion. These cracks are often the first visual sign that there is a corrosion problem. Cracks caused by corrosion must not be repaired simply by filling or sealing. These defects should be repaired by methods that apply Principles 7 to 11.

The possibility of further movement of the cracks adversely affecting the repair should be considered. Further information concerning live and dead cracks is given another part of standard of this series.

It should be noted that method 1.8 (applying membranes) may be equally applicable to Principles 2. 6 & 8.

A.6.2.1.3 Principle 2- Moisture Control

Moisture control is used in the repair of concrete to control adverse reactions by allowing the concrete to dry, as well as preventing moisture build-up. Adverse reactions may include alkali-silica reaction and sulphate attack. Saturated concrete may also be susceptible to freeze-thaw damage.

Surface protection systems applied to vertical and soffit surfaces should be permeable to water vapour to allow moisture to escape from the concrete.

Upper surfaces of horizontal concrete members (e.g. a suspended floor slab in a car park) may have an impermeable surface protection system applied.

Surface protection systems should not normally be applied to concrete containing excess moisture and product manufacturers should advise on appropriate application conditions

A.6.2.1.4 Principle 3- Concrete Restoration

Concrete restoration is normally carried out using either hand-applied patch repairs or recasting with flowing concrete or mortar, or applying concrete or mortar by spraying. Replacing of elements may include materials other than reinforced concrete.

A.6.2.1.5 Principle 4- Structural Strengthening

It is essential when using Principle 4 that all stresses associated with a repair and the original or deteriorated structure are considered. Certain systems may impose additional stresses on the repaired structure, resulting in changes in the original structural function.

While injecting or surface sealing cracks will not structurally strengthen a structure, injection may be used to restore the element to its structural condition prior to cracking (e.g. when temporary overloading has occurred).

A.6.2.1.6 Principle 5- Increased Physical Resistance

Removal of the concrete surface by physical actions, such as impact or abrasion, may affect the structural or durability performance of the structure. The causes need to be identified and physical protective measures may need to be taken to reduce their effects, as well as applying the repair methods.

A.6.2.1.7 Principle 6- Increasing resistance to chemicals

Where concrete has been attacked, the chemicals will need to be identified and suitable preventive measures may need to be taken, as well as applying the repair methods.

The resistance of concrete to different classes of environmental attack is defined in KS EAS 131-1:2008.

This Kenya Standard covers products and systems which may protect the concrete against environmental attack by chemicals listed in KS EAS 131-1:2008 and to severe chemical attack by chemicals.

Under certain conditions, soils, water treatment works and sewage can generate acids or sulfates or bacterial action that can promote attack on the concrete and reinforcement.

A.6.2.2 Principles and methods concerning reinforcement corrosion

A.6.2.2.1 General

Clause A.5.2.2 provides background information on repair. Principles 7 to 11 in Table 1 does not provide detailed comments on the individual sub-clauses in the normative text.

Reinforcement may be at risk of corrosion for a wide variety of reasons, including poor quality or missing concrete cover, contamination e.g. by chlorides, advancing carbonation, or other physical, chemical or electrochemical effects.

A.6.2.2.2 Carbonation

Where the reinforcement is protected by some remaining uncarbonated cover, methods 1.2, 1.3 and 1.7 as shown in Table 1 are examples that may be used to reduce access of carbon dioxide to the concrete.

Where the reinforcement is in contact with carbonated concrete the passivity will have been lost and corrosion may begin. A variety of methods can be used to control corrosion in this situation, using one or more Principles and Methods.

As well as carbon dioxide, other air-borne acidic pollutants, such as sulphur-dioxide, can attack both concrete and reinforcement in areas whore pollution is high, for example in chimneys.

A.6.2.2.3 Chlorides or other corrosive contaminants

Corrosion caused by the ingress of chloride ions is more difficult to treat than corrosion caused by carbonation.

The presence of chloride ions at the depth of the reinforcement breaks down the passive layer in uncarbonated concrete and allows corrosion to begin. Where elevated chloride ion contents have been detected then there is a risk that reinforcement corrosion can occur. The concentration that triggers corrosion varies in each individual case and depends on many factors including the cement type, w/c-ratio, the source of chloride, the alkalinity of the concrete and the exposure environment.

The source of the chloride ion is also important, in particular whether the chloride was cast into the concrete at the time of construction, or entered the concrete subsequent to hardening. For a given chloride ion content, chloride which has entered the concrete from an external source is more aggressive in terms of corrosion risk. Corrosion risk can also be increased by carbonation of concrete containing relatively low concentrations of chloride ion.

Traditionally, a figure of 0.4% by weight of cement was used as the threshold above which reinforcement corrosion would occur. More recent research shows the figure can be much lower than this, sometimes below 0.2%, although in certain environmental conditions much higher values can be tolerated. Therefore it is important to calibrate the risk of corrosion against the actual prevailing conditions of each structure and no "safe" limit should be assumed (Osmolska, Hornbostel, Kanstad, Hendriks, & Markeset, 17 September 2020).

Reinforcement corrosion can also be caused by halides other than chlorides, or other water-soluble chemicals.

Treatment of local areas of concrete that are contaminated by chloride ion can be successfully carried out by patch repair that removes all the contaminated concrete. However, where contamination is extensive, treatment of areas of damage alone will not provide a lasting repair solution. Areas repaired with new mortar or concrete can initiate corrosion in adjacent areas of contaminated concrete (often termed incipient anode or ring anode effect). In these situations, additional methods will need to be considered if corrosion is to be arrested, such as those given in Principles 7 to 11.

A.6.2.2.4 Principle 7 – Preserving or restoring passivity

A.6.2.2.4.1 General

The methods related to treating or replacing the concrete surrounding the reinforcement to reduce risk of corrosion.

A.6.2.2.4.2 Method 7.1-Increasing cover with additional mortar or concrete

Where the reinforcement is passive, an additional layer of mortar or concrete may be added over carbonated concrete to provide additional protection.

A.6.2.2.4.3 Method 7.2-Replacing contaminated or carbonated concrete

Where reinforcement has lost protection as a result of carbonation or chloride ion ingress, the structure may be repaired by replacing the contaminated or carbonated concrete with new concrete or mortar in accordance with method 7.2. Additional protection may be required in the form of a surface protection system in accordance with Principle 1. In the case where chloride ions remain in the concrete, there will be a risk of recontamination of the repair by diffusion and incipient anodes forming on reinforcement in the surrounding concrete. In these situations, other repair methods may need to be considered.

A.6.2.2.4.4 Method 7.3-Electrochemical realkalisation of carbonated concrete

Where the reinforcement is active or passive, additional corrosion protection can be provided by electrochemical realkalisation, which raises the alkalinity of carbonated concrete and provides passivity to the reinforcement.

The application of suitable coatings may extend the life of the treatment.

A.6.2.2.4.5 Method 7.4-Realkalisation of carbonated concrete by diffusion

There is limited experience with this method, but different approaches have been used in some parts of Kenya in certain situations.

One approach involves application of a highly alkaline cementitious concrete or mortar to the surface of carbonated concrete, allowing the concrete to be re-alkalised through diffusion from the surface.

A.6.2.2.4.6 Method 7.5 - Electrochemical chloride extraction

Where the reinforcement is active or passive due to chloride ion ingress, additional corrosion protection can be provided by electrochemical chloride extraction, which reduces the chloride ion content in the concrete surrounding the reinforcement and provides passivity.

A.6.2.2.4.7 Principle 8 – Increasing resistivity

Internally, in dry buildings, corrosion is seldom a problem even if the concrete is carbonated at the depth of the reinforcement. This is because the low moisture content in enclosed buildings tends to raise the resistivity of the concrete to a level where the corrosion rate is insignificant.

In some situations, the resistivity of external concrete may be reduced through the application of ventilated external cladding, water-repellent surface treatments, pore-filling impregnation or surface coatings (Principles 1 and 2). The technique for reducing the corrosion rate by limiting the moisture content, for example by over-cladding, is limited to situations where concrete can be prevented from taking up water from other sources. Also, the escape of moisture from the concrete should not be impeded.

With chloride-contaminated concrete, the risk of corrosion is more significant. Methods that increase the resistivity of the concrete may not be adequate in themselves to reduce corrosion of the reinforcement. In this situation, additional repair Principles may be needed.

The technique for reducing the corrosion rate by limiting the moisture content, for example by over-cladding, is limited to situations where concrete can be prevented from taking up water from other sources.

A.6.2.2.4.8 Principle 9 – Cathodic Control

Principle 9 relies upon restricting access of oxygen to all potentially cathodic areas, to the point when corrosion cells are stifled and corrosion is prevented by the inactivity of the cathodes.

A.6.2.2.4.9 Principle 10 – Cathodic Protection

Cathodic protection is especially appropriate where chloride contamination is significant, or carbonation to the depth of the reinforcement is extensive, resulting in a high risk of corrosion of reinforcement.

Impressed current cathodic protection applied according to ISO 12696 can control corrosion regardless of the level of chloride contamination in the concrete and limits the amount of concrete removal to that physically damaged by corrosion of underlying reinforcement. Its long term effectiveness depends on adequate monitoring and maintenance.

Cathodic protection is effective for achieving long-term corrosion control and counteracts the incipient anode problem and the effect of concrete contamination.

There are many different types of external anode systems used in cathodic protection, some of which use an impressed current from an external power source, while others use galvanic (sacrificial anode) action.

A.6.2.2.4.10 Principle 11 – Control of anodic areas

Where contamination of the concrete is extensive, and it is not possible to remove all contaminated concrete, incipient anode formation can be controlled by treating the surface of the reinforcement in the patch repair to prevent corrosion. Coatings can be applied directly to the reinforcement where it is exposed as part of concrete restoration. These coatings can contain active pigments, which may function as anodic inhibitors or by sacrificial galvanic action.

Other types of coating can form barriers on the surface of the reinforcement. This method can only be effective if the reinforcement is prepared to be free of corrosion and the coating is complete (i.e. the bar must be completely encapsulated and the coating is defect-free). The method should not be considered unless the whole of the circumference of the reinforcing bar can be coated. The effect of the coating on bond between the reinforcement and concrete should also be considered.

Alternatively, corrosion inhibitors can be used that chemically change the surface of the steel or form a passive film over it. Corrosion inhibitors can be introduced either by addition to the concrete repair product or system, or by application to the concrete surface followed by migration to the depth of the reinforcement. Inhibitors that are applied to the surface of the concrete must penetrate the concrete down to the level of the reinforcement to take effect. There is currently no standard for inhibitors, so evidence of the effectiveness of any such product should be obtained before specifying its use.

Note that some corrosion inhibitors work by control of both anodic and cathodic areas (see Principle 9).

In severe conditions, additional repair principles may be required.

A.6.2.3 Protection against and repair of reinforcement corrosion by methods not specifically mentioned in this Kenya Standard

Concrete protection and concrete repair are rapidly developing technologies and new methods of protection and repair are frequently proposed, developed and applied on a trial basis. This is especially true where reinforcement corrosion is the cause of the defects. Some such methods may not have an extensive history of previous use, yet may prove to be effective in appropriate circumstances.

A.7 Properties of products and systems required for compliance with the principles of protection and repair

To avoid any possible confusion, it is intended that the properties of a system for concrete repair should be tested and compared with the relevant performance requirements in other standards of this series. It is not intended that each component product of a system is tested and evaluated individually against the performance requirements unless the products can be used by themselves to meet the performance requirement.

For example, the properties of a surface protection system for a car park deck may contain multiple products such as a primer, elastic layer, sealing layer and wearing layer, each layer being of the thicknesses specified by the manufacturer. Compliance with the performance requirements is measured on the system applied in accordance with the manufacturer's recommended values and this would be stated alongside the CE Conformity symbol on the packaging of the products that comprise the system.

Particular attention is required lo the temperature and humidity conditions at application, because most repair products have been formulated to perform within a given range of ambient application conditions.

A.8 Maintenance following completion of protection and repair

Upon completion of concrete repair works, a maintenance management system should be implemented to ensure that the required future maintenance is carried out.

Parts of the protected or repaired concrete may have an expected service life that is short in comparison with the rest of the concrete structure. Examples include surface protection systems, sealants, and weatherproofing materials. Should the integrity of the structure depend on the performance of such products and systems, it is essential that they are regularly inspected, tested and renewed if necessary.

The following listing gives information for future maintenance which should be included:

a. An estimate of the expected remaining design life of the concrete structure;
b. Identification of each product and system where the design life is expected to be less than the remaining design life of the concrete structure;
c. The date at which each product and system is next to be inspected or tested;
d. The method of inspection to be used, including how results are to be recorded and how future inspection dates are to be decided:

e. A specification for systems with continuous treatment and monitoring, for example as used in an impressed current cathodic protection system;
f. A statement of precautions to be taken or restrictions to be applied, for example maintenance of surface water drainage, maximum pressure for water washing or prohibition of the use of de-icing salt.

A.9 Competence of Personnel

Personnel should be appointed who are familiar with protection and repair of concrete works and recognised as competent. This requirement requires to all persons involved in the repair process, including repair scheme designers, repair contractors and repair works inspectors.

A quality system should be employed by the repair contractor to ensure that the specified quality requirements are met and that the right repair methods are used.

Appropriate arrangements should be made for acceptance inspection.

All documents relating to the repair work should be stored in a suitable project management system

