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Earthen floors — Design and construction — Code of practice

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Foreword

Rwanda Standards are prepared by Technical Committees and approved by Rwanda Standards Board of (RSB) Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by members of RSB Board of Directors for publication and gazetted as Rwanda Standards.

DRS 311 was prepared by Technical Committee RSB/TC 009, *Building materials and civil engineering*.

In the preparation of this standard, reference was made to the following standard:

SAZ 724: 2005 *Rammed earth structures — Code of practice*

The assistance derived from the above source is hereby acknowledged with thanks.

This second edition cancels and replaces the first edition (RS 311: 2016), clauses 1, 2, 3 and 9 and annexes; B and A of which have been technically revised. Clauses 4, 5 and 6 have been. . Clause 9 has been changed to clause 5. Clauses 8 and 7 have been combined into clause 4. Annexes D, E, F, G and H have been added to the standard.

Committee membership

The following organizations were represented on the Technical Committee on *Building materials and civil engineering* (RSB/TC 009) in the preparation of this standard.

EarthEnable

Green Effect Engineering Rwanda

Institut d'Enseignement Supérieur de Ruhengeri (INES-Ruhengeri)

NPD Ltd

RULIBA Clays Ltd

Rwanda Housing Authority (RHA)

Rwanda Public Procurement Authority (RPPA)

Rwanda Transport Development Agency (RTDA)

Standards For Sustainability Rwanda

Strawtec

University of Rwanda - College of Science and Technology (UR-CST)

Rwanda Standards Board — Secretarial

Earthen floors — Design and construction — Code of practice

1. Scope

This Draft Rwanda Standard t gives guidance on the design and construction, performance criteria and test methods for earthen floors. It is limited to impervious earthen floors for use in residential buildings of classes R4 and R5 and where applicable in educational buildings of Class E1 under normal use conditions.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

RS 107, Building Sands from natural sources – Specifications

RS ISO 22475-3, Geotechnical Investigation and Testing Sampling Methods and Groundwater Measurements Laboratory Testing of Soil - Part 3: Standard Penetration Test

ASTM D 6024 – Standard Test Method for Ball Drop on Controlled Low Strength Material (CLSM) to Determine Suitability for Load Application

ISO 11890-2:2013: Paints and varnishes -- Determination of volatile organic compound (VOC) content -- Part 2: Gas-chromatographic method

ASTM C805 – 13a: Standard Test Method for Rebound Number of Hardened Concrete

3. Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1

earthen floor

a floor made of raw earth or other unworked ground materials. It is constructed on a stabilized sub-base, composed of selected granular soils mixed to a thickened consistency, spread with a mixture of sand with or without binders or fibers such as clay, straw and ounce dry is sealed with a drying oil or other impermeable surface sealants

3.2

varnish

any liquid surface coating that dries after application, conferring favorable stabilization properties.

3.3

soil stabilization

alteration of soils to enhance their physical properties, the shear strength and/or control the shrink-swell properties of a soil, to improve the load bearing capacity of a sub-grade to support foundations.

3.4

Stabilized Earthen Floors

Earthen floors whose sub base has been mechanically or chemically stabilized to enhance its soil bearing capacity but also to improve the overall performance of the earthen floor with respect to other properties such as impact resistance, abrasion resistance, impermeability and bearing capacity.

3.5

Optimum moisture content (OMC)

water content in percentage at which a soil can be compacted to a maximum dry unit weight by a given compactive effort

NOTE In this context a soil is dry when no further water can be removed at a temperature within the range of 105 °C ± 5 °C for 24 h.

3.6

normal use

any residential use of a floor where a uniformly distributed load of 1.92kN/m^{2}kN/m^2 is not exceeded

3.7

wearing surface

surface of an earthen floor that will come in contact with people and objects inside the house

3.8

competent authority

any person that has been legally appointed or invested by authority, institution of engineers or construction inspection, verification or execution.

3.9

safe materials

any building material that is not known to cause harm to users or the environment.

3.10

Sub-base material

material below the wearing surface of the floor which provides the structural stability of the floor.

3.11

R-4 Building Class

occupancy consisting of two or more dwelling units on a single site

3.12

R-5 Building Class

occupancy consisting of a dwelling unit on its own site, it may include a garage and other domestic out buildings, if any. It will usually be occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

3.13

E-1 Building Class

Educational building class that ranges from preschool to secondary level and whose sub-division shall include any building or a group of buildings under single management, which is used for students not less than 20 in number

3.14

datum

horizontal plane of known height to which the elevation of all other points is referenced. The mean sea level is the level generally adopted as a datum. It is used to establish the required depths for levelling the floor with respect to the adjacent grade level

4. Design and Construction

4.1 General requirements

4.1.1 The design and construction requirements in this standard shall be used in conjunction with the requirements of the relevant sections Rwanda Building Code.

4.1.2 Earthen floors and perimeters shall be built to prevent the entrance of runoff from rain and flooding.

4.1.3 The designer shall also define and state the design life of the earthen floor including periodic maintenance and repairs

4.2 Design considerations

4.2.1 Choice of materials

4.2.1.1 Different regions of the country shall have different building materials with varying properties.

4.2.2.2 Selection of materials shall be based on their performance as according to the requirements stated in clause 5

4.2.2.3 When selecting material, the designer shall also take into account the thicknesses of each layer of the floor pavement, and where necessary determine the subsurface water, the geographical location of the area with respect to its geological and hydrological factors.

4.2.2 Thermal performance

4.2.2.1 Light-coloured floors reflect and radiate heat, dark-coloured floors mainly re-radiate heat only and therefore absorb and conduct a high proportion of solar heat gain to the backing (base and sub-base of the floor).Consideration should be given to sub-floor insulation to enhance the thermal performance of an earthen floor. These characteristics may be used in the design of thermally efficient buildings

4.2.2.2 Where it is suspected that thermal movement of the floor may be excessive, special precautions such as provision of movement joints should be considered.

4.2.2.3 Earthen floors shall be designed to resist thermal cracking and shrinkage. Provision shall be made to accommodate movement due to shrinkage expansion or settlement of the threshold between 2 rooms.

4.2.3 Durability

4.2.3.1 The structure shall be designed such that deterioration over its design working life does not impair the performance of the earthen floor below that intended, having due regard to its environment and the anticipated level of maintenance.

4.2.3.2 The degree of any deterioration may be estimated on the basis of calculations, experimental investigation, experience from earlier constructions, or a combination of these considerations.

4.2.3.3 in order to achieve an adequately durable structure, the following shall be taken into account :

a) environmental conditions shall be identified at the design stage so that their significance can be assessed in relation to durability and adequate provisions can be made for protection of the materials used in the structure

b) composition, properties and performance of the materials and products ;

c) properties of the soil ; and

d) quality of workmanship, and the level of control

4.2.3.4 The wearing surface of finished floors shall meet the performance criteria defined in clause 5.

4.3 Construction

4.3.1 General

4.3.1.1 Earthen floors shall be substantially levelled to follow a degree slope towards the door to allow the surface-runoff of water from the interior.

4.3.1.2 Sub-soils shall be compacted to a minimum bearing capacity of 50 kPa to meet the performance criteria defined in clause 5. In situ subsoils may meet this capacity without replacement or improvement.

4.3.1.3 The floor shall be without sharp changes in height (e.g. between different surfaces or between individual bricks) of more than ± 5 mm over a 300 mm straight edge, other than for a step into a different room.

4.3.2 Surface finish and coatings

4.3.2.1 Surface coating materials such as natural products, chemical products, and combinations of products which form an external protection against earthen floor wear and resistance to penetration by water or other fluids.

4.3.2.2 Surface coatings for earthen floors may consist of materials such as natural oils or waxes, or other proprietary sealants or products with equivalent or improved properties.

4.3.2.3 Surface coatings shall be safe materials

4.3.2.4 Flatness or surface regularity is a measure of the deviations from a plane over a large area of the floor, as well as over small local areas. Some variations in surface level can be allowed without detriment to the satisfactory performance of the floor.

4.3.2.5 the floor shall be without sharp changes in height (e.g. between different surfaces or between individual bricks) of more than ± 5 mm over a 300 mm straight edge

4.3.3 Departure from datum and surface regularity

4.3.3.1 The maximum departure from the finished floor level should be specified, taking into account the area of the floor and its use.

4.3.3.2 Greater accuracy to datum may be needed in small rooms, along the line of partition walls, in the vicinity of door openings and where specialized equipment is to be installed directly on the floor

4.3.3.3 Tolerances for floor levels should be the following:

a) within one room the variation from corner to corner or from the datum should be not more than ± 15 mm;

b) the variation over a 2 m long straight edge should be not more than ± 10 mm.

4.3.4 Moisture control

4.3.4.1 Earthen floors should be protected from rising moisture so that it does not penetrate the floor.

4.3.4.2 If floors are intended to be washed, the floor surface should be waterproofed, and the junction of floor and walls should be protected with a suitable raised skirting.

4.3.5 Settlement and cracking

Floors shall be structurally independent of the walls to avoid excessive cracking due to wall loadings and settlement of footings.

5. Performance criteria

5.1 General

Key performance metrics shall be evaluated no earlier than 7 days after completion of an earthen floor or after visible drying, whichever is longer. The floor shall pass these same performance metrics 1 year after completion.

Earthen flooring is routinely cast in-situ within actively occupied residential homes, necessitating the provision of minimally to non-destructive field tests that can approximate laboratory-grade tests. Laboratory tests shall be carried out for quality assurance purposes when deemed necessary by a competent authority.

5.2 Compressive strength

5.2.1 The sub-floor (under the wearing surface) shall resist all loads typical of buildings classes specified inin this standard. The compressive strength shall be verified by compliance with the test in Annex B.

5.2.2 Dry compressive strength values for unstabilized earthen floor should be at least 1.5 MPa after 1 month curing.

5.3 Wearing surface hardness

The wearing surface of the floor that people interact with should be hard enough to withstand point loads including tables, benches, beds, and shoes, verified by compliance with the test in Annex D and Annex F

5.4 Resistance to abrasion

The floor shall be able to withstand scratching and gouging under normal use, including the movement of wooden furniture. Resistance to abrasion shall be measure in accordance to Annex H

5.5 Resistance to water

The floor shall be able to withstand absorption of water due to cleaning/washing as defined in Annex G

5.6 moisture absorption

Finished earthen floor shall have a low moisture absorption rate not exceeding 4 %. Absorption can be measured according to Annex B.

Annex A
(informative)

The roll test

A.1 Procedure

A.1.1 Take a handful of unsieved soil sample, moisten, make into a ball, and leave to dry in the sun. If it falls apart it has too little clay, and is thus unsuitable for earthen floors: look for another soil source.

A.1.2 If the ball remains together when dry, crush the soil to remove any lumps. Add water slowly.

A.1.3 Make a ball and place it on hard ground. Take a 10 mm diameter reinforcing bar, 500 mm long, and stand it vertically, with its end resting on the middle of the ball of damp soil.

A.1.4 Let it sink in under its own weight. (Do not push it). When the bar sinks in exactly 20 mm, the water content is right for doing the test.

A.1.5 Take enough of the damp soil to form a ball in your hands; then between your hands form into a roll 25 mm thick and 200 mm long. Place the roll on a table, and push it gently over the edge.

A.1.6 Measure how long it gets before it breaks off. Check the length of the piece that drops.

A.2 Result

If the roll breaks off less than 80 mm, there is not enough clay. If the roll breaks off longer than 120 mm, there is too much clay.

NOTE Any other equivalent standard test method shall be used.

Annex B
(normative)

Water absorption test

B.1 Procedure

B.1.1 Take five samples, preferably smaller samples as they can be dried out more quickly. The samples should weigh at least 500 grams.

B.1.2 Weigh each sample and then dry it out on either a hot plate or an oven until no further weight reduction is recorded. Then expose the samples to constant saturation or immersion for 2 hours days, dry off the surface level water with an absorbent cloth or napkin, and weigh them again.

B.1.3 In the absence of accurate weighing equipment, absorption can be assessed by the dimensional difference between a dry and a wet sample.

B.1.4 Prepare the samples in the same way as above, and accurately measure the dry and wet dimensions. Expansion when wet should be at most 4 % for stabilized earthen floor.

B.2 Results

The absorption shall be the increase in weight of the wet sample as a percentage of the dry weight (Average the results from the five samples).

Annex C
(Informative)

Recommended material choices

C.1 Earthen mixes

C.1.1 Soils used to form earthen floors should be free from organic material and other non-soil substances, such as plastics, leaves, dung, or other deleterious material.

C.1.2 Earthen floors may be viably constructed using a wide range of protocols, each designating a specific range of soil, gravel, and clay ratios. The composition of any component soil may be approximated by a bottle test, described in Annex F or a roll test described in Annex A. Laboratory gradation tests can be performed for more accurate data.

C.1.3 The purpose of stabilization is to improve soil properties such as increasing compressive strength, reducing the variations in cohesion and volume caused by changes in moisture content, reducing the erosive effect of water on the surface, or by combinations of these. Stabilization should use any safe material that strengthens the floor if required.

C.2 Water

Water used for ramming should be from a clean source. It should be free from organic material and any other harmful substances. In general, potable water may be used for preparation of earthen mixes.

C.3 Surface sealants

C.3.1 Surface coatings such as natural products, chemical products, or combinations of products, may be used as a waterproof covering which form an external protection against earthen floor wear and resistance to penetration by water or other fluids. Surface coatings for earthen floors may consist of materials such as natural oils or waxes, or other equivalent products.

C.3.2 Surface coatings must contain very little volatile organic carbon (VOC) compounds, containing no more than 50g of VOC/L. At no time during application or during surface curing may butanone oxime levels exceed 20µg/m^3, nor shall total VOC exceed 1500 µg/m^3. Requirements for measuring VOC shall be done in accordance with ISO 11890.

C.3.3 Surface coatings must contain no more than 90 mg elemental lead per kg of liquid coating. Ideal surface coatings should be lead-free, containing no more than 15µg/kg of elemental lead.

Annex D
(Informative)

Flat rock test

D.1 Procedure

D.1.1 Find a flat rock with a 20 cm - 25 cm in diameter (e.g. a piece of gravel). Place it onto the floor's subfloor sub-base after compaction and drying of any admixtures or moisture, so that it is thus ready for the wearing surface to be added.

D.1.2 Have a person with weight varying from 60 kg to 90kg (or an equivalent load) step onto the flat rock, and apply their full weight for 30 seconds.

D.1.3 Record the depth of the resulting indentation.

D.2 Results

Floors with acceptable compressive strength will not sink more than 3 mm in depth

Annex E
(Informative)

Sedimentation bottle shake test

E.1 Procedure

E.1.1 Fill a 1.5 l clear bottle 50% with the material of interest.

E.1.2 Add water until 75% full.

E.1.3 Shake the bottle vigorously until the water and material are thoroughly mixed.

E.1.4 Allow the material to settle for 30 min.

E.2 Results

The top layer will be clear water, the next layer will be clay, then silt, then sand/rocks. To measure the percentage of clay, divide the height of the clay layer by the height of the full height of non-water material.

Annex F
(Normative)

Ball-indentation hardness test

Ball-indentation test shall be carried out in accordance with ASTM D6024 or where using a Schmidt hammer test as per ASTM C805 – 13a, depending on the available equipment.

F.1 Procedure

F.1.1 The indenter shall be a hardened and polished steel ball. The ball shall not show any deformation or damage after the test. The ball shall have a 25.4 mm diameter and a mass of 70.0 g (+/- 0.7g)

F.1.2 Elevate the indenter at a height of 500 mm (+/- 10 mm) over the surface of a level, dry, earthen floor that has been wiped free of surface contamination.

F.1.3 Release the ball and record the diameter of the indentation using callipers. Move to a new location within 5 m, and repeat the test for a total of three impacts per floor.

F.2 Results

F.2.1 If the standard error is greater than 2 mm, repeat the test until the error is below 2 mm

F.2.2 If the mean diameter of indentations is less than 7.5 mm, the floor is suitable for normal use applications.

Annex G
(Normative)

Swipe Test

G.1 Procedure

G.1.1 Clean a 10 cm x 10 cm square patch on the floor by wetting the floor, and wiping gently with a moistened cloth. This removes loose dirt sitting on top of the floor.

G.1.2 Flood the 10 cm x 10 cm square and allow it to sit for 1 minute.

G.1.3 Wipe the square vigorously with a new cloth, and evaluate transference of sand and clay particles to the cloth.

G.2 Results

Floors with acceptable resistance to water induced erosion will not transfer sand and clay to the wiping cloth.

Annex H
(Normative)

Finger Nail Scratch Test

H.1 Procedure

H.1.1 Wet a 10 cm x 10 cm square of floor and wipe it dry.

H.1.2 Scratch the floor surface with one's thumbnail, or a Moh’s hardness standard of 2.

H.1.3 Wipe the floor with a moistened wipe.

H.2 Results

Floors with acceptable abrasion resistance will not leave a scratch mark

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