BRITISH STANDARD

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14487-2:2006

Sprayed concrete —

Part 2: Execution

The European Standard EN 14487-2:2006 has the status of a British Standard

ICS 91.100.30

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National foreword

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Contents

Foreword

This document (EN 14487-2:2006) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2007, and conflicting national standards shall be withdrawn at the latest by April 2007.

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1 Scope

This European Standard is applicable to sprayed concrete to be used for ground strengthening, repair and upgrading of existing structures and for free-standing structures.

The standard specifies requirements for the execution of concrete spraying both by wet and dry process.

The standard is applicable to temporary as well as permanent structures.

This standard does not cover safety and health aspects of execution.

This standard does not state requirements for quality assurance and for qualification of personnel for the various activities.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 206-1:2000, *Concrete — Part 1. Specification, performance, production and conformity*

EN 1504-3, *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 1504-10, *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*

ENV 13670-1, *Execution of concrete structures — Part 1: Common*

EN 14487-1:2005, *Sprayed concrete — Part 1: Definitions, specifications and conformity*

EN 14488-6, *Testing sprayed concrete — Part 6: Thickness of concrete on a substrate*

EN 14889-1, *Fibres for concrete — Part 1: Steel fibres — Definitions, specifications and conformity*

EN 14889-2, *Fibres for concrete — Part 2: Polymer fibres — Definitions, specifications and conformity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14487-1:2005 apply.

4 Documentation

4.1 Project specification

The project specification shall include all necessary information and technical requirements for execution of the works.

As a minimum the following shall be stated:

— type of project (bridge, house, road, railway, hydro power, etc.),

— purpose of concrete spraying (permanent or temporary support etc. for ground strengthening), (structural or non structural for repair),

— inspection category according to EN 14487-1,

— requirements related to health and safety,

— qualification of personnel,

— requirements on quality assurance plan for execution if required,

NOTE 1 Quality plan for execution is normally required for inspection classes 2 and 3.

— relevant European Technical Approvals and provisions valid on the construction site,

NOTE 2 Provisions valid at the construction site are national standards and documents approved by competent authority defined in the project specification.

— procedures for making alterations to previously agreed requirements,

— list of relevant design documents.

for ground strengthening also:

— general type of ground conditions (rock type and quality etc.),

— main principles applied for the sprayed concrete ground strengthening design,

— any particular execution conditions (e.g. frozen substrate, spraying under compressed air, special waste deposits).

for repair, upgrading and free-standing structures also:

— requirements on surface finish,

— requirements on thickness.

— main structural design principles and objectives

NOTE 3 Informative Annex A contains a checklist of requirements and information that may have to be included in the project specification as appropriate.

Before commencement of execution of any part of the works, the project specification relevant to that part of the works shall be complete and available. The project specification should also include statements on requirements for the distribution, the filing and recording of technical documents used for the works.

4.2 Execution documentation

If required, a quality plan for the execution of the work shall be prepared including a complete listing of relevant references. References shall, where appropriate, be given to requirements and conformity criteria in EN 14487-1.

The sprayed concrete execution shall be documented according to requirements put forward in this standard and the established QA plan.

5 Preparatory works

5.1 For strengthening of ground

5.1.1 Preparation of substrate

All poor or loose rock shall be removed.

Ground water leakages are to be collected in hoses, pipes or other drainage systems, to prevent detriment to the quality of the sprayed concrete.

Any specified rock mechanics instrumentation shall be installed.

5.1.2 Removal of dust and debris

Dust debris and other deposits shall be removed by pressurised water jetting prior to spraying.

5.1.3 Pre-wetting

The need for additional pre-wetting prior to spraying shall be considered taking into account the suction of the substrate and the consequent risk of an adverse influence on the sprayed concrete.

5.1.4 Protection against extreme ambient temperatures

When working in high or low temperatures, precautions shall be taken to ensure the quality of the sprayed concrete.

If the ambient temperature is expected to be below 0 °C at the time of spraying or in the curing period, precautions shall be planned to protect the concrete against damage due to freezing.

If the ambient temperature is forecast to be high at the time of spraying or in the curing period, precautions shall be planned to protect concrete against damaging effects.

5.2 For repair, upgrading and free-standing structures

5.2.1 Scaffolding, falsework and formwork

Scaffolding, falsework and formwork shall, generally, apply to ENV 13670-1.

For scaffolding and falsework for sprayed concrete operations, the following additional clauses shall be considered:

— it shall be strong enough to take all the loads including the produced rebound, without undue deformations,

— it shall accommodate the safe working of the nozzleman,

— it shall be placed such that a sufficient distance between nozzle and surface of application can be achieved (see 9.1),

— it shall allow easy access to all parts of the members to be treated.

Formwork for sprayed concrete operations shall be designed so as to avoid pockets of rebound.

5.2.2 Preparation of substrate

It is essential that sprayed concrete is applied to a thoroughly clean, rough and defect-free surface. High pressure water jetting or grit blasting, capable of etching the substrate surface, are the recommended methods.

For repair and upgrading, the preparation of concrete substrate and reinforcement shall conform to EN 1504-10.

5.2.3 Pre-wetting

For repair and upgrading, pre-wetting of the substrate of the existing concrete (or other porous material) shall be considered according to EN 1504-10.

5.2.4 Protection against extreme ambient temperature

Formwork or structural parts in contact with the section to be sprayed shall have a temperature which does not result in freezing of the sprayed concrete before it has sufficient strength to resist the effects of freezing.

If the ambient temperature is expected to be below 0 °C at the time of spraying or during the curing period, precautions shall be taken to protect the concrete against damage due to freezing.

If the ambient temperature is expected to be high at the time of spraying or during the curing period, precautions shall be taken to protect concrete against damaging effects.

6 Reinforcement

Reinforcement steel may be mesh, reinforcement bars or fibres.

For ground strengthening, lattice girders and steel ribs may be incorporated in the sprayed concrete, under separate materials specification.

Reinforcement in terms of mesh or bars for sprayed concrete structures shall comply with ENV 13670-1.

Steel or polymer fibres used for reinforcement shall comply with EN 14889-1 or EN 14889-2 respectively.

Additionally:

— reinforcement is to be fixed in such a way, that it will stay in place and not vibrate during the spraying process,

— design and the arrangement of the rebars shall be adapted for the spraying process in order to minimize the shadow effect and improve compaction.

— where two or more layers of mesh reinforcement are incorporated, the rear layer should be encased in sprayed concrete prior to fixing the next front layer (not applicable to necessary overlaps within a layer) which shall be fixed at a distance of at least 2 times the maximum aggregate size from the preceding sprayed concrete layer.

Pressurised air used shall be freed from oil by using adequate equipment (e.g. oil traps).

7 Equipment

7.1 Storage of materials

Constituent materials shall be stored and handled so that their properties do not change significantly, e.g. by action of climates, intermingling or contamination, and that their conformity with the respective standard is maintained.

Storage compartments shall be clearly marked in order to avoid errors in the use of the constituent materials.

Special instructions from the suppliers of the constituent materials shall be taken into account.

Facilities shall be provided to enable samples to be taken from the stockpiles, silos and bins.

7.2 Batching equipment

When factory blended dry mixes are used, they shall comply with EN 1504-3. For site mixes, the performance of the batching equipment shall be such that under practical operating conditions the maximum tolerances stated in Table 1 shall be achieved.

Table 1 — Accepted tolerances for the batching and spraying process of constituent material

Constituent material	Accepted tolerances % of specified quantitiy	
	Inspection category 2	Inspection category 3
Cement	± 5 %	± 3 %
Water (for wet process only)	± 5 %	± 3 %
Total aggregates	± 5 %	± 3 %
Additions	± 5 %	± 3 %
Fibres	± 5 %	± 5 %
Admixtures added at batching place and used at ≤ 5 % by mass of cement	± 7 %	± 5 %
Materials added at the nozzle	± 10 %	± 5 %
NOTE The tolerance is the difference between the target value and the measured value		

The accuracy of the measuring devices shall comply with the relevant national requirements or regulations valid in the place of use of the concrete. In the absence of such requirements, provisions in accordance with EN 206-1:2000, clause 9.6.2.2 applies.

7.3 Mixers

For wet and dry spraying methods, the mixer shall be capable of achieving a uniform distribution of the constituent materials.

7.4 Spraying equipment

When an accelerator is used, the dosage device shall ensure that the accelerator content of the sprayed concrete is maintained within the ranges given in Table 1 for materials added in the nozzle.

Note Usually the concrete flow is not constant with time, therefore the rate of addition of the accelerator is synchronised with the concrete output.

When using steel or polymer fibres, the length of the fibres shall not exceed 70 % of the internal diameter of the pipes or hoses used, unless a test has demonstrated that longer fibres can be sprayed without blockage.

7.5 Testing equipment

All necessary facilities, equipment and instructions for its proper use, shall be available when required for inspections and tests on equipment, materials and concrete.

Relevant test equipment shall be in calibration at the time and the procedure shall be recorded.

8 Batching, mixing and delivery of concrete

8.1 Batching and mixing

Cement, aggregates, fibres, admixtures and additions in the form of powders shall be batched by mass. Other methods including measuring by volume are permissible if the required batching accuracy can be achieved and this is documented.

Mixing shall be carried out until the mix has a homogenous appearance. Special care shall be taken in case of fibre addition, in order to ensure a uniform dispersion in the mix.

Any mix spilt during handling or ejected from the spraying machine shall not be re-used.

8.2 Delivery

8.2.1 Dry mix process

Appropriate measures shall be taken to ensure that the fresh concrete remains sufficiently workable until end of spraying.

Dry mix compositions with moist aggregate shall normally be applied within 90 minutes after mixing. If more than 90 minutes is required until end of the spraying of a batch, the open time provided by the chosen measures shall be demonstrated and verified in advance.

Dry mix compositions with oven dried aggregate may be stored for a limited time but shall be applied immediately after mixing with water. Oven dried material should be pre-dampened before the nozzle or before it is loaded in the spraying machine.

When quickset cement is used the procedure shall be adjusted to allow for the limited open time of the mix.

Detrimental changes in the dry mix, such as segregation, shall be minimized during loading, transport and unloading as well as during conveying on site.

8.2.2 Wet mix process

Appropriate measures shall be taken to ensure that the mixed concrete remains sufficiently workable until the end of spraying. The normal workability time shall be determined by pre-construction tests. If the work requires longer workability times it shall be verified by additional tests.

Detrimental changes to the base mix, such as segregation, bleeding, paste loss or any other changes shall be minimized during loading, transporting and unloading as well as when being conveyed on site.

9 Execution of spraying

9.1 Spraying

For spraying of concrete, the following general rules apply.

Before spraying, always control concrete temperature and slump at site.

To adjust the concrete stream through the nozzle (air pressure, accelerator and concrete stream), the nozzle has always to be turned away from the substrate.

Sprayed concrete shall be composed and sprayed in a manner to limit rebound. Important factors influencing rebound: concrete composition, nozzle angle and distance to substrate, accelerator dosage, area of application in the tunnel, etc.).

The nozzle shall be directed, wherever possible, normally to the application surface, to produce a layer of optimum density and thickness, with full encasement of reinforcement and minimum rebound. No pushing or sliding of sprayed concrete has to occur. Deviation from the optimum nozzle distance and nozzle angle may produce increased rebound and reduced sprayed concrete quality.

The distance between the nozzle and the surface is determined according to site conditions and the possibility to obtain good compaction, full encasement of the reinforcement and minimum rebound. For rock support normally a distance of 1 m - 2 m is recommended. The specified sprayed concrete thickness may necessitate the application of two or more layers in order to avoid sagging and sloughing. This applies in particular to overhead work.

The thickness of each concrete layer depends on several parameters and shall be based on site conditions and composition of the mix. The thickness of the layer may be increased by the use of admixtures (e.g. accelerators), additions (e.g. silica fume) or the use of quick-setting cements.

A subsequent layer shall not be applied before the preceding layer is able to support it.

If considerable time passes between the placement of the different layers to obtain the specified total thickness the previously sprayed concrete surface shall be cleaned either by air blowing, high pressure washing, brushing or sand blasting and pre-wetted as specified in clause 5..

For application on irregular and rough rock contours (e.g. drill and blast excavation), an extra smoothening layer may be specified. If so, this has to be executed first.

Sprayed concrete in place shall be of a homogenous composition without any inclusion of rebound.

Overspray and loose rebound material shall be removed from surrounding areas and from the substrate before sprayed concrete is applied.

When spraying on or through reinforcement, the consequence of rebound and shadow effects shall be carefully taken into account. Although the shadow effect cannot be avoided, efforts shall be done to minimize possible negative effects and particular attention has to be paid to:

— Ensuring that the air stream velocity around the bar is sufficient. This condition is fulfilled either with an appropriate distance between the nozzle and the rebars or with a stronger air stream to carry the mix.

— Encapsulation of reinforcement shall be completed as soon as practical, ensuring that the required concrete cover on reinforcement is achieved. It is to be noted that the same requirements regarding concrete cover apply to a rough sprayed surface as for a cast smooth surface.

— Preventing poor compaction, if spraying with steel fibre concrete onto other types of reinforcement.

— Pre-wetted substrates shall be free from running water.

9.2 Surface of finished concrete

As hand-finishing of freshly sprayed concrete may be detrimental to adhesion and strength, in general the sprayed concrete shall be left as sprayed unless the properties of the sprayed material allow otherwise and are documented.

If a special surface texture is required, an additional treatment may be used, e.g. by applying a finish-layer that is treated to the desired texture.

9.3 Curing and protection

Curing is to be done in order to minimise plastic shrinkage, ensure adequate durability and inter-layer bond strength.

After completion of spraying, the surface shall be cured without delay. This applies also to intermediate steps of spraying, if the next layer is to be applied more than 2 hours later.

For concrete that will be exposed to exposure classes X0 or XC1 conditions only, the minimum curing period shall be 12 h, provided that the surface concrete temperature is equal to or above 5 °C.

Unless other requirements are specified in national standards or provisions valid at the construction site, the following shall apply:

— Sprayed concrete that will be exposed in exposure classes other than X0 or XC1 shall be cured until the strength has reached at least 50 % of the specified compressive strength class. Prescribed sprayed concrete shall be cured for at least an equivalent period.

— National standards or provisions valid at the construction site may translate the above requirement into an equivalent period of time.

Curing may be achieved using a curing compound which is sprayed onto the concrete surface, or by an admixture added to the concrete during mixing. The curing compound shall be removed before application of the next concrete layer. The effect of the curing product used shall be verified by preconstruction tests or by other relevant

documentation.Field tests of the bond between layers (inter-layer bond strength) shall be carried out prior to commencement of work. Field tests shall be carried out if changing to a new type of curing material.

Steps shall be taken to protect against frost when spraying in cold weather, or when spraying against frozen rock or soil. Such protection shall be in place until the sprayed concrete has developed a compressive strength of at least 5 MPa.

10 Geometrical tolerances

10.1 General

If geometrical tolerances are required, ENV 13670-1 applies.

10.2 Thickness

Provision shall be taken in order to control the thickness of the concrete during spraying. Suitable methods include the use of spacers, inserts, guide wires and profile boards.

If required or specified, the thickness of sprayed concrete after spraying shall be determined in accordance with EN 14488-6.

For fibre reinforced sprayed concrete the control of thickness shall be performed before applying any further unreinforced layer.

The frequency of thickness and conformity control shall be stated in the specification.

11 Inspection

11.1 General

Inspection shall ensure that the works are completed in accordance with this standard and the provisions of the project specification.

The extent of the inspection is related to the inspection category classification given in EN 14487-1.

EN 14487-1 applies for tests on constituent materials, basic mix and sprayed concrete.

Components bearing CE-marking or third party product certification shall be checked against those appearing on the delivery ticket and usually inspected. In case of doubt, further inspection shall be undertaken to check that the products conform to the specification. Other components shall be subjected to inspection and acceptance testing as defined in the project specification.

11.2 Scope for inspection of execution

The scope of inspection to be carried out is given in Table 2 unless otherwise stated in the project specification.

Table 2 — Scope of inspection

Subject	Inspection category 1	Inspection category 2	Inspection category 3
Planning for inspection	No requirements	Inspection and test plan, procedures and instructions as specified. Actions in the event of a non-conformity	
Scaffolding, falsework and formwork	Visual inspection	Major scaffolding and formwork to be inspected before spraying	All scaffolding and formwork to be inspected before spraying.
Preparation of substrate and pre-wetting	Visual inspection	Major surfaces to be inspected before spraying	All surfaces to be inspected before spraying
Protection against extreme ambient temperatures	Visual inspection and temperature measurement		
Reinforcement	Visual inspection and random measurements	Major reinforcement to be inspected before spraying	All reinforcement to be inspected before spraying
Embedded items	Visual inspection	According to project specification	
Storage of materials	Visual inspection		
Batching equipment	Visual inspection	Inspection of supplier's test documentation	Random measurements on constituent materials
Mixers	Visual inspection		
Spraying equipment	Visual inspection	Inspection of supplier's test documentation	Random measurement of material output and accelerator dosage.
Testing equipment	Visual inspection		
Batching and mixing	Visual inspection		
Delivery of concrete	Visual inspection	Random control of open time (dry mix) and workability time (wet mix)	
Spraying of concrete	Visual inspection		
Surface finishing	Visual inspection		
Curing and protection of concrete	Visual inspection	Random temperature and humidity measurement during spraying and curing period.	Frequent temperature and humidity measurement during spraying and curing period.
As-built geometry	Visual inspection	According to project specification	
Documentation of inspection	Records from all unusual events All non-conformities and report of corrective actions taken	All planning documents Records from all inspections All non-conformities and report of corrective actions taken	

11.3 Inspection actions related to the scope of inspection

Table 3 — Inspection actions related to the scope of inspection

X: normally applicable

Inspection actions	Ground strengthening	Repair and Upgrading		Free-standing structure
Planning for inspection	X	X	X	X
Scaffolding, falsework and formwork				
Geometry and stability of formwork		X	X	X
Tightness of formwork		X	X	X
Removal of detritus (dust, debris, etc) from section to be sprayed		X	X	X
Preparation of surface of the formwork		X	X	X
Estimation of concrete strength for adequacy before removal of formwork		X	X	X
Preparation of substrate and pre-wetting				
Rock descaling executed according to specification	X			
Substrate clean, moistened but with no running water	X	X	X	
Required rock mechanics instruments are installed	X			
Ground water point drainages have been installed where required	X			
Protection against extreme ambient temperatures				
Protection against frost	X	X	X	X
Protection against high temperature, extreme ventilation, etc	X	X	X	X
Reinforcement				
Mesh and bars				
Type and placing in accordance with drawings and specifications	X	X	X	X
Properly tied and secured against displacement during spraying	X	X	X	X
Not contaminated by deleterious substances (oil, grease, paint, etc)	X	X	X	X
Sufficient space between bars to allow full compaction	X	X	X	X
No unnecessary overlaps between bars	X	X	X	X
Cover of concrete in accordance with specification	X	X	X	X
Steel and polymer fibres				
Type and content according to specification	X	X	X	X

Table 3 — *(continued)*

Inspection actions	Ground strengthening	Repair and Upgrading		Free-standing structure
Embedded items				
Type and placing in accordance with drawings and specification		X	X	X
Properly tied and secured against displacement during spraying		X	X	X
Storage of materials				
Protection against moisture	X	X	X	X
Not contaminated by deleterious substances	X	X	X	X
Batching equipment	X	X	X	X
Mixers	X	X	X	X
Spraying equipment				
Accuracy of accelerator dosage device	X	X	X	X
Testing equipment				
Visual inspection	X	X	X	X
Delivery of concrete				
Check that the specified open time or workability time is not exceeded	X	X	X	X
Check homogeneity of concrete material fed into the spraying equipment	X	X	X	X
Spraying of concrete				
Sufficient supply of compressed air to achieve good compaction	X	X	X	X
Low enough accelerator dosage to avoid concrete build-up on the reinforcement	X	X	X	X
Well adapted spraying distance and the necessary variation of spraying angle	X	X	X	X
Surface finishing				
Check that surface finishing is performed according to specification		X	X	X
Curing and protection				
Verify that curing of the sprayed concrete is executed as specified	X	X	X	X
Sprayed-on curing compound removed according to specification, before placing any additional layer of sprayed concrete	X	X	X	X
As-built geometry				
Measure thickness	X	X	X	X
Documentation	X	X	X	X

Annex A
(informative)

Guidance on documentation

Table A.1 gives a summary of information that should be included in the project specification, as relevant, in order to be in accordance with this standard.

Table A.1 — Checklist of information for inclusion in the project specification

Section	Text	Ref
1. Scope	Specify specific project requirements	4.1
	Specify requirements relating to health and safety	
	Specify requirements relating to qualifications of personal	
	Define responsibilities where appropriate	
2. Normative references	Add all relevant national standards or provisions valid at the construction site	2
3. Documentation	All necessary technical information to be set out in the project specification	4.1
	National provisions that need to be respected	
	Include procedure for altering project specification	
	Requirement for document distribution	
	State if quality plan is required	
	State if execution documentation is required	
4. Preparatory works	Specify provisions for application of release agents	5.2.1
	Specify any requirements for surface finish, special finish or trial panels	9.2
5. Reinforcement	Specify types of reinforcement	6
	Specify provisions for reinforcing steel	
	Provide cutting and bending schedules or identify that this is a task for the constructor	
	If bending at temperature below –5 °C is permitted, specify the precautions to be taken	
	State if bending using heating is permitted	
	Specify any requirements to straighten bent bars	
	Provisions for welding reinforcement	
	Confirm that spot welding is permitted	
	Provisions for joints in reinforcement	
	Location or reinforcement including the position of joints	
6. Equipment	Specify the requirement for storage of all materials	7.1
7. Execution of spraying	Check that all required concrete properties have been specified	4.1
	State if trial spraying is required	9.2
	State any additional limits for the concrete surface	9.3
	Provisions for translating percentage of compressive strength to periods of time	
	State any restrictions for curing compounds on concrete surface	
	State if higher peak temperatures are acceptable	5.2.4
8. Geometrical tolerances	State any requirements relating to aesthetics	10
9. Inspection	Specify inspection category and define who is responsible for the inspection	11.1
	Specify provisions relating to inspection personal	
	Define inspections and acceptance testing of products without a CE-marking or third party certification	

Bibliography

[1] EN 934-5, *Admixtures for concrete, mortar and grout — Part 5: Admixtures for sprayed concrete — Definitions, requirements, conformity, marking and labelling*

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