SRI LANKA STANDARD 1253 : 2015

UDC 666.942.7

SPECIFICATION FOR

PORTLAND LIMESTONE CEMENT

(Second Revision)

SRI LANKA STANDARDS INSTITUTION

Sri Lanka Standard
SPECIFICATION FOR PORTLAND LIMESTONE CEMENT
***(Second Revision*)**

SLS 1253 : 2015
(incorporating corrigendum No. 1)

(Attached Amd 483)

Gr. 10

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Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.

This standard does not purport to include all the necessary provisions of a contract.

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Sri Lanka Standard
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(Second Revision)

FOREWORD

This standard was approved by the Sectoral Committee on Building and Construction Materials and was authorized for adoption and publication as a Sri Lanka Standard by the Council of the Sri Lanka Standards Institution on 2015-11-19.

This standard was first published in the year 2003 and was revised in 2008. This is the second revision of the standard. Portland Limestone Cement (PLC) is cement with many beneficial properties, but it is still cement which is undergoing development and acceptance. Detailed information on its performance is not yet freely accessible, except for specialists in this field. Hence it was considered necessary to provide access to current knowledge on PLC to the local users. Appendix **B** is included specially to satisfy this need. Further criterion for differentiation of rapid hardening and normal hardening cement was also introduced.

This specification has been prepared to enable manufacturers to produce PLC equivalent to Ordinary Portland Cement (OPC) on the basis of compressive strength at 2 days, 7 days and 28 days.

For the purpose of comparison of cement type given in this standard with those given in **BS EN 197-1,** corresponding equivalent cement type with respect to **BS EN 197-1** is given where applicable.

Appendix **C** of the standard provides some guidelines on the use of cement while Appendix **D** gives some useful information on adulterated cement. This current revision of the standard refers to relevant SLS ISO standard test methods.

Further guidance on usage of this cement with respect to other cements in Sri Lanka (see Appendix **E**) is also included to satisfy a pressing need of the cement users.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or observation shall be rounded off in accordance with **SLS 102**. The number of significant places retained in the rounded off value shall be the same as that of the specified value in this standard.

In the preparation of this standard the assistance derived from the publications of the International Organization for Standardization (ISO), European Committee for Standardization (CEN) and British Standards Institution (BSI) are gratefully acknowledged.

1 SCOPE

This standard covers the requirements for constituents, composition, mechanical properties, physical properties, chemical properties, packaging, marking and delivery of Portland Limestone Cement (PLC).

This specification pertains to four strength classes of PLC.

NOTE: *Requirements for other cements are covered in separate Sri Lanka standards (see Clause* ***2****).*

2 REFERENCES

ISO 2859-1	Sampling procedures for inspection by attributes - Part 1
BS 8500	Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier
BS EN 196-6	Method of testing cement Part 6: Determination of fineness
BS EN 197-1	Cement - Part 1: Composition, specifications and conformity criteria for common cements
BS EN 206-1	Concrete - Specification, performance, production and conformity
BS EN 933-9	Tests for geometrical properties of aggregates Part 9: Assessment of fines - Methylene blue test
BS EN 934	Admixtures for concrete, mortar and grout
BS EN 13639	Determination of total organic carbon content in limestone
SLS 102	Rules for rounding off numerical values
SLS 107	Specification for Ordinary Portland Cement
SLS 428	Random sampling methods
SLS 515	Specification for Masonry Cement
SLS 1247	Specification for Blended Hydraulic Cements
SLS ISO 679	Methods of testing cements – Determination of strengths
SLS ISO 9597	Cement - Test methods - Determination of setting time and soundness
SLS ISO 29581-1	Cement - Test methods - Part 1: Analysis by wet chemistry
SLS ISO 29581-2	Cement - Test methods - Part 2: Chemical analysis by X-ray fluorescence

3 DEFINITIONS

For the purpose of this standard, the following definitions shall apply;

3.1 additives : Constituents other than main constituents, minor additional constituents or calcium sulphate which are added to improve the manufacture or the properties of the cement, such as grinding aids, pigments or pack set inhibitors.

3.2 cement : An inorganic finely ground hydraulic binder which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.

3.2.1 composite sample : Homogeneous mix of spot samples taken

a) at different points; or
b) at different times,

from a supply of cement in the bulk or bag form obtained by thoroughly mixing the combined spot samples and, if necessary, reducing the size of the resulting mix.

3.3 consignment : Quantity of cement delivered at a given time by a single manufacturer, factory, depot or dispatching centre. It may consist of one or more lots.

3.4 increment : Quantity of cement taken in a single operation of the sampling equipment used.

3.5 laboratory sample : Sample prepared by thoroughly mixing and if necessary reducing from a large composite sample (spot or composite sample) and intended for use by laboratories undertaking the tests.

3.6 lot : In any consignment or part of a consignment, all the packages of cement or quantity of bulk cement belonging to one batch of manufacture or supply shall constitute a lot.

3.7 main constituent : Specially selected inorganic material used in a proportion exceeding a total of 5 % (m/m) related to the sum of all main and minor additional constituents (see **5.1** and **5.2**).

3.8 manufacturer : The establishment responsible for the quality of cement manufactured.

3.9 minor additional constituents : Specially selected inorganic materials used in a proportion not exceeding a total of 5 % (m/m) related to the sum of all main and minor additional constituents. (see **5.1** and **5.2**).

3.10 percent (m/m) : Mass of a constituent expressed as a percentage of the total mass of the constituents.

3.11 packer/distributor : The establishment responsible for the quality of cement packed and/or distributed in Sri Lanka.

3.12 sample : Quantity of cement taken at random, in accordance with the specified sampling plan, from a large quantity (cement stored in silo, stock of bags, wagons, trucks, etc.) or from a fixed lot, relating to the intended tests. A sample may consist of one or more increments.

3.13 sample for retest : Sample which is to be kept for possible subsequent test in the event of the results from tests carried out on laboratory samples being in doubt or dispute.

3.14 spot samples : Samples which is taken at the same time and from one and the same place, relating to the intended tests, and which can be obtained by combining one or more immediately consecutive increments.

3.15 strength class of cement : Class of compressive strength as specified in Table **2**.

4 PORTLAND LIMESTONE CEMENT (PLC)

Portland Limestone Cement (PLC) conforming to this standard shall consist of an intimate and uniform blend of Ordinary Portland Cement (OPC) and limestone, and it is produced either by intergrinding Portland cement clinker, limestone and gypsum, or by blending OPC and finely ground limestone.

5 CONSTITUENTS

5.1 Main constituents

5.1.1 *Portland cement clinker*

Portland cement clinker is a hydraulic material made by sintering a precisely specified mixture of raw materials (raw meal, paste or slurry) containing elements, usually expressed as oxides, CaO, SiO_2, Al_2O_3, Fe_2O_3 and small quantities of other materials. The raw meal, paste or slurry is finely divided, intimately mixed and therefore homogeneous.

Portland cement clinker shall consist of at least two-thirds by mass of calcium silicates ($3CaO.SiO_2$ and $2CaO.SiO_2$). The remainder shall consist of aluminium and iron containing clinker phases and other compounds. The ratio by mass CaO/SiO_2 shall be not less than 2.0. The magnesium oxide, MgO content shall not exceed 5.0 % (m/m) when determined in accordance with **SLS ISO 29581-1**.

5.1.2 *Limestone*

Limestone shall meet the following requirements:

The calcium carbonate ($CaCO_3$) content calculated from the calcium oxide content in accordance with **SLS ISO 29581-1** shall be at least 75 % (m/m).

The clay content, when determined by the methylene blue test in accordance with the test method given in **BS EN 933-9**, shall not exceed 1.20 g/100 g. For this test the limestone shall be ground to a fineness of approximately 500 m^2/kg determined as specific surface in accordance with **BS EN 196-6.**

The total organic carbon (TOC) content, when tested in accordance with the test method given in **BS EN 13639** shall not exceed 0.20 % (m/m).

5.2 Minor additional constituents

At the option of the manufacturer, minor additional constituents may be used in the manufacture of PLC provided the total amount of such materials shall not exceed 5.0 % (m/m) related to the sum of all main and minor additional constituents of the cement.

Minor additional constituents are specially selected, inorganic natural mineral materials, inorganic mineral materials derived from the clinker production process or constituents as specified in **5.1** unless they are included as the main constituents in the cement.

Minor additional constituents, after appropriate preparation, and on account of their particle size distribution, improve the physical properties of the cement (such as workability or water retention). They can be inert or have slightly hydraulic, latent hydraulic or pozzolanic properties. However, requirements are not specified for them in this respect.

Minor additional constituents shall be correctly prepared, i.e. selected, homogenized, dried and comminuted depending on their state of production or delivery. They shall not increase the water demand of the cement appreciably, impair the resistance of the concrete or mortar to deterioration in any way or reduce the corrosion protection of the reinforcement.

NOTE: *Information on the minor additional constituents in the cement should be available from the manufacturer on request.*

5.3 Calcium sulphate

Calcium sulphate is added to the other constituents of cement during its manufacture to control setting.
Calcium sulphate can be gypsum (calcium sulphate dihydrate, $CaSO_4.2H_2O$), hemihydrates (partially dehydrated gypsum $CaSO_4.{}^1/_2H_2O$) or anhydrite (anhydrous calcium sulphate $CaSO_4$) or any mixture of them. Gypsum and anhydrite are found naturally. Calcium sulphate is also available as a by-product of certain industrial processes.

5.4 Additives

Additives for the purpose of this standard are constituents not covered in **5.1** to **5.3** which are added to improve the manufacture or the properties of the cement.

The total quantity of additives shall not exceed 1.0 % (m/m) of the cement (except for pigments). The quantity of organic additives on a dry basis shall not exceed 0.2 % (m/m) of the cement. A higher quantity may be incorporated in cements provided that the maximum quantity, in percentage, is declared on the packaging and/or the delivery note.

These additives shall not promote corrosion of the reinforcement in concrete or impair the properties of the cement or of the concrete or mortar made from the cement.

Admixtures for concrete, mortar or grouts in dry form shall not be incorporated in BHC conforming to this standard.

When admixtures for concrete, mortar or grouts conforming to the **BS EN 934** series are used in cement the standard notation of the admixture shall be declared on bags or delivery documents.

6 COMPOSITION

The composition of the PLC shall be as shown in Table **1**.

TABLE 1 - Composition of the PLC

Designation (1)	**Equivalent cement type in BS EN 197-1** (2)	**Composition** % (m/m)		
		Main constituents		**Minor additional constituents** (5)
		Clinker (3)	**Limestone** (4)	
Portland Limestone Cement	CEM ll/A-LL	80 to 94	6 to 20	0 to 5

7 MECHANICAL, PHYSICAL AND CHEMICAL REQUIREMENTS

7.1 Mechanical requirements

The compressive strength of mortar prisms shall be determined in accordance with **SLS ISO 679** at the laboratory temperature of 27 ± 2 ^{0}C.

The moist air room or the cabinet for storage of the test specimens in the mould shall be continuously maintained at the temperature of 27 ± 1 ^{0}C and a relative humidity not less than 90 %. The temperature of the water in the storage container of test specimens shall be maintained at 27 ± 1 ^{0}C.

7.1.1 *Standard strength*

The standard strength of cement is the compressive strength of mortar prisms determined at 28 days and shall conform to the requirements given in column **4** of Table **2.**

Two classes of standard strength are included in this standard. i.e. Class 32.5 and Class 42.5 (see column **1** of Table **2**).

7.1.2 *Early strength*

The early strength of cement is the compressive strength of mortar prisms determined at either 2 or 7 days and shall conform to the requirements given in column **2** or **3** of Table **2** respectively**.**

Two classes of early strength are included for each class of standard strength, a class with ordinary early strength indicated by N and a class with high early strength indicated by R.

7.2 Physical requirements

7.2.1 *Initial setting time*

The initial setting time of cement paste of standard consistency as determined by the method described in **SLS ISO 9597** shall conform to the requirements given in column **5** of Table **2**.

TABLE 2 - Compressive strength and setting time requirements

Strength class	**Compressive strength** N/mm^2			**Initial setting time** min **(5)**
	Early strength		**Standard strength**	
(1)	**2 day** **(2)**	**7 day** **(3)**	**28 day** **(4)**	
32.5 N	-	≥ 16.0	≥ 32.5 ≤ 52.5	≥ 75
32.5 R	≥ 10.0	-		
42.5 N	≥ 10.0	-	≥ 42.5 ≤ 62.5	≥ 60
42.5 R	≥ 20.0	-		

7.2.2 *Soundness*

The cement shall not have an expansion of more than 10 mm when tested for soundness by the method described in **SLS ISO 9597.**

7.3 Chemical requirements

In determining the chemical composition of cement, either the analysis by wet chemistry described in **SLS ISO 29581-1** or by X-ray fluorescence (XRF) technique given in **SLS ISO 29581-2** may be used. In the case of dispute, unless otherwise agreed by all parties, only the test methods described in **SLS ISO 29581-1** shall be used.

The chemical properties of all strength classes of the cement shall conform to the requirements listed in Table **3**.

TABLE 3 - Chemical requirements

Property **(1)**	**Strength class** **(2)**	**Requirement** % (m/m) **(3)**
Magnesia content	All	≤ 5.0
Sulphate content (expressed as SO_3)	32.5 N, 32.5 R, 42.5 N	≤ 3.5
	42.5 R	≤ 4.0
Chloride content	All	≤ 0.10
Loss on ignition	All	≤ 10.0

8 MARKING

8.1 PLC manufactured in compliance with this standard shall be marked on the bag legibly and indelibly with the particulars as given in **(a)** to **(h)**. When supplied in bulk, manufacturer's certificate, the delivery note or the invoice shall also provide the following information:

a) Name and address of the manufacturer (see **3**.**9**);

b) Name and address of the importer, packer and distributor, where relevant (see **3.12**);

c) Generic name of the product in Sinhala, Tamil and English;

that is : පෝට්ලන්ඩ් හුණුගල් සිමෙන්ති

போர்ட்லேண்ட் சுண்ணாம்புக்கல் சீமெந்து

Portland Limestone Cement

d) Strength class: e.g. 42.5 N (see Table **2**);

e) The week of manufacture and the date of packing;

f) Net mass of the contents, in kg, if packed in bag or, in tonne (1000 kg), if supplied in bulk;

g) Any other information required in the standard

eg: type of admixture used, loss on ignition (if applicable), etc; and

h) Best before date (as declared by the manufacturer).

NOTE 1: *Attention is drawn to the product certification marking facilities offered by the Sri Lanka Standards Institution. See the inside back cover of this standard.*

NOTE 2: *For the "best before" date to be valid, cement should be delivered, stored and used as specified in Appendix* **C**.

8.2 In the case of bagged cement the size of the letters used for **(c)** and (**d)** shall be not less than 12 mm in height.

8.3 In the case of bagged cement brand name, SLS mark (if applicable) and generic name should be displayed on the front side of the bag. Information in Figure **1** should be displayed on the rear side of the bag.

පෝට්ලන්ඩ් හුණුගල් සිමෙන්ති போர்ட்லேண்ட் சுண்ணாம்புக்கல் சீமெந்து Portland Limestone Cement Strength class The name and address of the manufacturer, packer and the distributor SLS 1253 The week of manufacture and the date of packing Net mass in kg Best Before
Guidelines on usage of this cement are given in Appendix **E** of SLS 1253

FIGURE 1- Format for labelling the rear side of the cement bag

9 DELIVERY AND PACKAGING

The cement shall be supplied in bulk, or packed in bags with sufficient strength and constructed to prevent damage or deterioration of cement, during normal handling.

Any container used for bulk supply shall have an airtight fully enclosed body robust enough to prevent spillage of cement, and a special facility for dustless discharge such as air slide, pneumatic discharger or spiral conveyor.

When cement is supplied in bag form, the minimum net mass of each bag shall be 50.0 kg. The net mass of the bag of cement shall be determined by its gross mass and the mass of package. The nominal mass of the empty bag shall be marked to the nearest one gram on the package, where facilities exist for such marking. If mass of an empty bag is not displayed on the bag, mass should be determined by weighing 10 empty bags used for the same batch. These empty bags should be supplied by the manufacturer (see **3.9)** or packer/distributor (see **3.12**).

The bags of cement which are not in good condition, due to causes such as moisture patches, torn bags, burst stitches, spilling cement or exudation of cement dust, shall be rejected.

10 MANUFACTURER'S CERTIFICATE

The manufacturer/packer/distributor shall be satisfied that the cement at the time of its delivery complies with the requirements of this standard. In case of imported cement time of delivery means the time of delivery to a port in Sri Lanka.

The manufacturer/packer/distributor on request shall forward a certificate to this effect to the purchaser or his representative. The certificate shall include the results of tests on samples of cement relating to the material delivered.

Following test information shall be provided:

a) Test results relevant to mechanical, physical and chemical requirements.
b) Mineral composition of clinker.

11 INDEPENDENT TESTS

If the purchaser/end-user or his representative requires independent tests, they shall be carried out in accordance with this standard on the written instructions of the end-user or his representative.

The manufacturer/vendor shall supply, free of charge, the cement required for testing unless otherwise specified in the enquiry and order, the cost of the tests shall be borne as follows:

a) by the manufacturer/vendor if the results show that the cement does not comply with the requirements of this standard; and
b) by the end-user if the results show that the cement complies with the requirements of this standard.

12 SAMPLING

Where the compliance of a lot to the requirements of this specification is to be assessed based on statistical sampling and inspection, sampling scheme given in Appendix **A** shall be applied.

In case a sample is required for independent tests, it shall be taken, at the option of the end-user or his representative, before delivery or within one week after delivery of the cement as per Appendix **A**.

Where the compliance with this specification is to be assured based on manufacturer's control system coupled with type testing and check tests or any other procedures, appropriate schemes of sampling and any other inspection procedures can be adopted.

All the samples shall be directed to the testing authority with immediate effect and the tests shall be commenced within 4 weeks of the delivery of the sample to the testing authority.

13 INSPECTION AND TESTING

13.1 Inspection

13.1.1 *Lot supplied in bulk*

Where the cement supplied is in bulk form, each container shall be inspected at the sampling stage for the relevant delivery and packing requirements as per clause **9.**

13.1.2 *Lot supplied in bags*

Where the cement supplied is in bag form, each bag selected in **A.2.1**, shall be inspected at the sampling stage for the marking and packaging requirements specified in clause **8** and clause **9** respectively. Required facilities shall be provided by the manufacturer/vendor responsible for the quality or its representative.

13.2 Testing

The laboratory sample (see **A.3**) shall be tested for all the mechanical, physical and chemical requirements specified in clause **7**.

14 COMPLIANCE OF A LOT

Any lot, when sampled in accordance with clause **12**, fails to comply with any of the following requirements during the period declared by the manufacturer, shall be deemed not to comply with this standard.

14.1 Delivery and packing

14.1.1 *Lot supplied in bulk*

Each container shall comply with the relevant delivery and packing requirements in clause **9**.

14.1.2 *Lot supplied in bags*

a) Each bag in the sample drawn in accordance with clause **12** shall comply with the marking requirements given clause **8**

b) The number of bags not conforming to relevant delivery and packaging requirements in clause **9** shall be less than or equal to the corresponding acceptance number given in column **3** of Table **4**.

14.2 Laboratory sample

The laboratory sample (see **A.3**) shall comply with the mechanical, physical and chemical requirements given in clause **7**.

APPENDIX A
SAMPLING OF CEMENT

A.1 SAMPLING EQUIPMENT

A sampling tube (see Figure **2**) or an appropriate instrument shall be used.

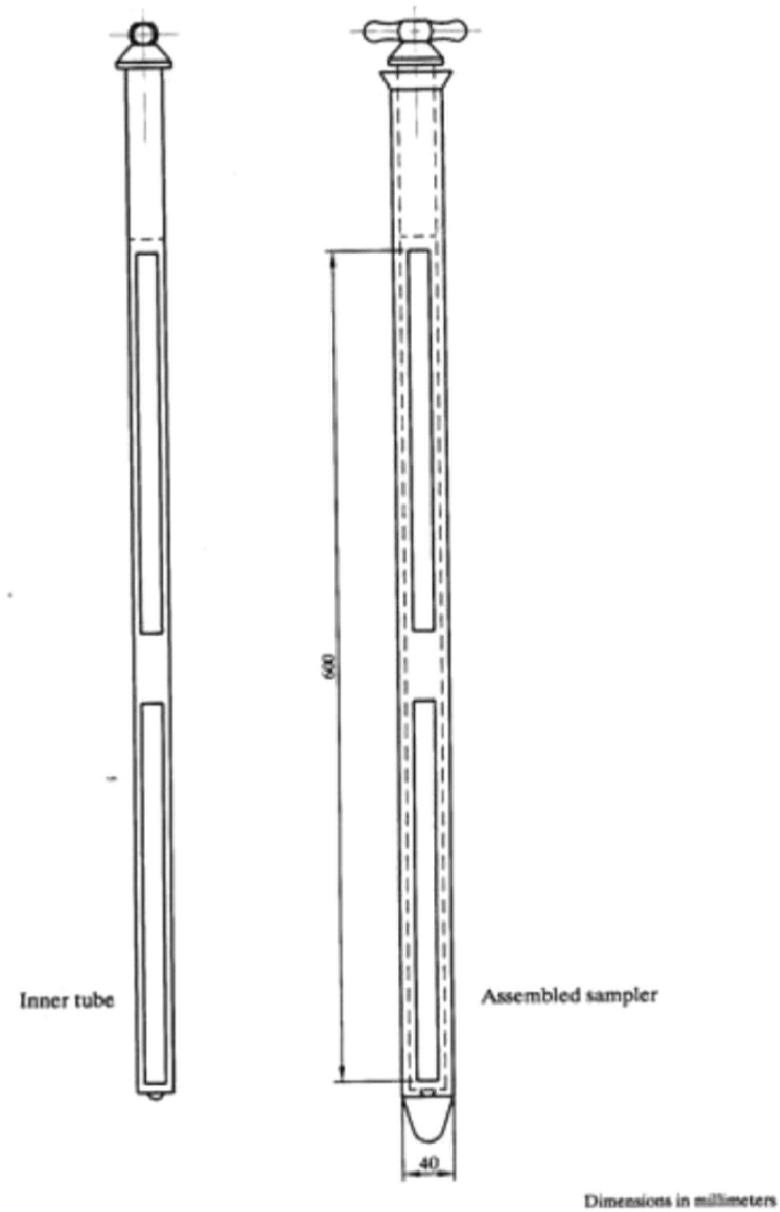

FIGURE 2 - Sampling Tube

A.2 SCALE OF SAMPLING

A.2.1 *Sampling from bags*

Where the cement packed in bags, the sample shall comprise the number of bags that is given in column **2** of Table **4**, selected at random from the lot in accordance with the lot size given in column **1** of Table **4**.

TABLE 4 - Scale of sampling

Lot size (*N*) (1)	Sample size (n) (2)	Acceptance Number (3)
Up to 280	08	00
281 to 1200	32	01
1201 to 3200	50	02

NOTE: *Table* **4** *was prepared in accordance with* **ISO 2859-1:1999** - *Sampling procedure for inspection by attribute and* ***Part 2*** - *Sampling schemes index by Accepted Quality Limit (AQL) for lot by lot inspection.*

To ensure the randomness of selection, a method given in **SLS 428** shall be used.

Alternatively all the bags in the lot may be arranged in a serial order and starting from any bag, every n^{th} bag be selected in order to meet the requirement given in column **2** of Table **4**, n being the integral part of *N*/n where *N* is the lot size (number of bags in a lot) and n is the sample size (number of bags have to be selected).

Approximately equal quantities of cement shall be taken from each bag selected and make composite sample in order to meet the requirements of laboratory sample (see clause **A.3**).

Appropriate sampling instrument described in **A.1** shall be used to collect the cement from the bags.

A.2.2 *Sampling from large containers and bulk transport (after loading or before unloading*)

Sufficient number of increments shall be drawn from evenly distributed points of each container (wagon, truck, etc...) and a composite sample shall be made in order to meet the requirements of laboratory sample (see clause **A.3**). Increments shall be taken by using a sampling tube or appropriate sampling instrument.

Care shall be taken not to take materials from the top and bottom layers of the mass of cement. The thickness of the layer to be considered is at least 150 mm.

A.2.3 *Sampling while charging or discharging*

Sampling shall be carried out with suitable increments at regular intervals when the cement is being charged into the container/silos or being discharged from the containers/silos and composite sample shall be made in order to meet the requirements of laboratory sample (see clause **A.3**). The increments shall be such that one increment is taken per 10 tonnes of cement or as per the agreement between the manufacturer (or vendor) and the customer (or purchaser). Appropriate sampling instrument shall be used.

A.3 LABORATORY SAMPLE

Prior to preparation of laboratory sample, the composite sample shall be carefully homogenized (in a laboratory) with clean dry implements, not liable to react with the cement.

Homogenization shall be achieved by a suitable mixing machine if available. In the absence of a mixing machine, careful mixing shall be done with a shovel on a clean dry surface.

Immediately after homogenization of sample, it shall be divided equally (see **Note**) into required number of laboratory samples by using a sample divider or other suitable means. The laboratory sample shall be of such a size that all the tests whatever specified can be carried out twice.

NOTE: *In general at least 5 kg of cement sample would be sufficient to carry out all the tests twice.*

A.4 PACKING AND STORAGE

The samples shall be packed, dispatched and stored in polyethylene/polypropylene (PE/PP) bags with thickness at least 100 μm or rigid containers made of material that is inert to cement and non-corrodible. They shall be dry, impervious (to air and moisture) and clean. In this respect they shall not have been used for packing products which are likely to affect the samples.

Each of the laboratory samples shall be divided into two equal portions and packed separately (second portion of the laboratory sample for retest if required).

To minimize the aeration,

a) Where the rigid container is used, it shall, as far as possible, be completely filled and their closure shall be sealed (integral seal or other suitable means).

b) Where the PE/PP bag is used, the air in the bag shall, as far as possible, be removed and provision shall also be made to seal them where necessary.

The samples shall be stored below 30 ^{0}C until commencement of testing.

NOTE: *It should be noted that packaging, however air-tight, cannot in the long term prevent a certain amount of aeration, which may vary depending on the properties of the packing material.*

APPENDIX B
INFORMATION FOR USERS OF PLC

History of Portland cement goes back to the early part of 19th century, however the systematic or scientific cement production started in early part of 20th century. Different kinds of blended cement are also manufactured very early days using slag and pozzolanas as additives replacing clinker. But until recently only OPC was widely used. Cement industry is an energy intensive industry and clinker burning process also releases various gasses affecting the environment. To overcome this, cement manufacturers introduced various types of alternative fuels for clinker burning and blended cements replacing clinker with various types of mineral additives. PLC is one such cement introduced more recently with the introduction of common cements in early 90's. However it has a long history especially in Europe. PLC was introduced to Sri Lanka in 2003 to be in line with the international practice.

PLC reduces the clinker content and introduces limestone, which means less burning, consumption of less energy in pyro-processing and comminuting [1] ,use of less limestone overall, and hence a reduction of CO_2 emissions making the cement more environmentally friendly. Introduction of efficient milling systems for grinding reduces electrical power, thus lowering CO_2 emission from the power station. Lesser use of clinker reduces CO_2 emissions from the cement plant [2].

As pure limestone or calcite is not normally available to cement plants, suitable limestone is specified [1] by imposing limits on $CaCO_3$ content, clay content and total organic carbon content. Greater clay content leads to increased water demand and reduced frost resistance. A limit is imposed on total organic carbon content because organic matter if present decays rapidly.

Although **BS EN 197-1** [3] allows limestone contents up to 35 % in PLC, in the **BS 8500** [4], [5] the use of PLC with up to 20% of limestone is allowed, just like OPC, in all exposure classes except very aggressive environments. In line with this thinking, this Sri Lanka standard limits the limestone content to a maximum of 20 % (m/m).

There are three mechanisms by which finely divided limestone can modify properties of Portland cement [2],[6]. Firstly, it improves the particle size grading of the cement paste in concrete, thus improving particle packing which reduces the water demand and reduces bleeding or segregation. Secondly, hydration rate is increased with fine particles of limestone providing nucleation sites for crystallization of $Ca(OH)_2$, C-S-H and carboaluminates. Lastly, a fraction of limestone interacts with the hydrating C_3A to form a monocarboaluminate phase and to become partially incorporated in the C-S-H phase. This monocarboaluminate phase is stable and co-exists with the monosulphate phase, which is the normal product of reaction between gypsum and C_3A. However, the practical effects of limestone additions in small amounts are physical [7], improving particle packing and providing nucleation sites for clinker hydration products [1].

To derive fully the benefits of PLC, particle size distribution (PSD) should be monitored. This generally requires closed circuit milling with high efficiency separators [1],[6]. The limestone is normally interground with clinker, which makes limestone to be more finely ground than clinker as limestone is the softer of the two. This enhances the reactivity of the $CaCO_3$ and improves particle packing.

It is normally lighter in colour than its parent OPC [6]. PLC should be stored under very dry conditions [8], since it can react rapidly with contaminations of moisture due to its higher fineness [9]. However, Sri Lankan users appear to be taking necessary precautions in this regard, with no complaints known to have received on hardening of PLC during usage of a cement bag.

There is a common belief that the finer the powdered material, the greater it becomes water demand, when it is made into an aqueous suspension. Such thinking assumes that the relative particle size distribution remains unchanged [9]. The easily ground limestone usually has a wide particle size distribution which allows the limestone particles to fill the gaps between the clinker particles, reducing the water demand and densifying the structure of hardened cement paste [1].

Bleeding is a form of segregation in which some of the water in the mix tends to rise to the surface of freshly placed concrete. This is caused by the inability to hold all of the mixing water when they settle downwards. Bleeding is decreased by increasing the fineness of cement, and PLC with a high fineness thus reduces bleeding [10].

Influence of PLC on heat of hydration and setting time was found to vary with some cement compositions recording an increase and other cement compositions recording a decrease [1]. The tendency to false set has been shown to be reduced with partial substitution of limestone for gypsum.

Limestone in PLC improves the particle size distribution by making it broader. The fine particles displace some of the water from the voids between the coarser particles, making it available as an additional “internal lubricant”. Thus the concrete is less stiff and water retention is improved [1]. Since less water is needed to make a workable mix, water cement ratio can be reduced so that the strength is increased. Further, this means that less stiff concrete with PLC is more easily consolidated by vibration. In practical terms this means that a PLC mix is more workable, easy to compact, easy to pump leading to reduced wear and tear on pumping equipment.

While good early moist curing is essential for blended cements with fly ash or pozzolana, the long term strength of PLC may be superior even with somewhat poor curing conditions as a result of its more rapid rate of initial hydration [6]. However, it must be emphasized that whatever be the type of cement used, proper curing should always be carried out.

PLC has less cemenitious matter in comparison to OPC. So the performance of PLC containing greater than 5 % limestone is akin to OPC with less cementitious material [11], [12]. In the case of this PLC which has a limestone content greater than 5 %, it may be necessary to increase the cementitious content by the proportion of the extra filler content (i.e 15 %), if PLC is to be used in a concrete of a nominal mix or a prescribed mix [13], unless tests show otherwise. It should be noted that for DC-2 close concrete (concrete subject to water pressure in a very aggressive exposure conditions rich in sulphates) even the **BS 8500** [4], [5] still recommends a higher cement content for PLC concretes [12], than for OPC, to compensate for the lower binder(clinker) content of PLC. This restriction is not applicable to design mixers. However, in the case of Grade 15 concrete such an increase can be ruled out on the basis of increased strength likely from use of a lower water/cement ratio with PLC.

Drying shrinkage and carbonation depths show mixed results, in some cases being increased and in some decreased in PLC when compared to OPC. The differences are of limited practical significance in the context of normal concrete mix variations [1].

Permeability is somewhat reduced in PLC mixtures, probably due more to a reduction in the connectivity of the pores rather than to their volume [1], due to closer packing caused by broader particle size distribution of limestone. This accounts for better corrosion protection than in OPC.

There are some concerns regarding *thaumasite* ($CaSiO_2.CaCO_3.CaSO_4.15H_2O$) formation when PLC concrete is exposed to sulphate-bearing ground water; particularly at temperatures below 15 ^{0}C. Rate of deterioration is similar to OPC under sulphate attack when *ettringite* ($C_3A.3CaSO_4.31H_2O$) rather than *thaumasite* is formed. In the case of *ettringite* formation, rate of deterioration is governed by clinker C_3A content. In the case of *thaumasite* formation, researchers differ on the role of C_3A, with some researchers showing that higher C_3A prevents *thaumasite* formation. The **BS 8500** [4], [5] removed restrictions on use of PLC for concrete foundations in certain soil conditions for normal usage , but still recommends a higher cement content of PLC, in comparison to OPC, for **DC-2** class very extreme exposure [12].

The performance of mineral admixtures is unaffected by limestone in PLC [1].

Plastic shrinkage is greater when cement content in the mix is high, concrete stiffens earlier, concrete temperature is higher than ambient and evaporation is high. When these factors are prevalent, all types of cement used in concreting including PLC give rise to plastic shrinkage cracking, unless evaporation is prevented by placing and finishing fast , and covering plastic concrete very early before the commencement of curing [8]. However there are patented methods of curing that can be used immediately after placement.

PLC is unlikely to affect adversely the resistance of the concrete to fire or to abrasion [14]. Normal shutter / formwork removal times apply to PLC as initial set and early strength are only slightly less than those of OPC. Further, because of faster hydration reaction, PLC is not very dependent on the efficiency of long term curing.

Although PLC has a slightly lower heat of hydration in comparison to OPC, it is not a low heat cement as C_3S and C_3A contents are not very much smaller than those of OPC, and because greater fineness causes faster hydration [8].

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APPENDIX C
GUIDANCE ON THE USE OF CEMENT

C.1 SAFETY WARNING

Dry cement in normal has no harmful effect on dry skin. When cement is mixed with water, alkali is released. Precautions should therefore be taken to avoid dry cement entering the eyes, mouth and nose and to prevent skin contact with wet cement.

Repeated skin contact with wet cement over a period may cause irritant contact dermatitis. The abrasiveness of the particles of cement and aggregate in mortar or concrete can contribute to this effect. Continued contact during a working day can lead to cement burns with ulceration but this is not common. Some people are sensitive to the small amounts of chromate which may be present in cement and can develop allergic contact dermatitis, but this is rare.

When working in places where dry cement becomes airborne, protection for the eyes, mouth and nose should be worn.

When working with wet mortar or concrete, waterproof or other suitable protective clothing should be worn such as long sleeved shirts, full length trousers, waterproof gloves and shoes. Clothing contaminated with wet cement, mortar or concrete should be removed and washed before further use.

If cement enters the eye it should immediately be washed out thoroughly with clean water and medical treatment should be sought without delay. Wet mortar or concrete on the skin should be washed off immediately.

C.2 STORAGE

To protect cement from premature hydration after delivery, bulk silos should be waterproof and internal condensation should be minimized.

Paper bags should be stored clear of the ground, not more than eight bags high and protected by a waterproof structure. As significant strength losses begin after several weeks of storage in bags in normal conditions, and considerably sooner under adverse weather conditions or high humidity, deliveries should be controlled and used in order of receipt.

C.3 GROUTING AND RENDERING

Where cement is to be used in grouts or renders that are pumped through small apertures, such as spray nozzles, it is recommended that the user passes the cement or suspension through a screen of suitable mesh aperture to retain any occasional coarse particles.

C.4 HEAT GENERATION

The cement hydration process generates heat, particularly in the first few days. Cements with higher early strength usually have a higher initial rate of heat generation than those with lower early strength. A higher initial rate of heat generation may be an advantage for thinner concrete sections, because it reduces the need for extended striking times. However, it may be a disadvantage for larger sections on account of the temperature gradients, which are set up.

C.5 FINENESS

A variety of Cement of different fineness is available. In general, fineness varies from about 300 m^2/kg to 400 m^2/kg with the latter value in the order of that of rapidly hardening Portland cement. If the selection of a cement is to be based on fineness, the advantages and disadvantages listed below should be taken into account with respect to the specific application under consideration.

Cement with a greater fineness has the following advantages:

a) possesses a higher volume per unit mass and hence yields greater volume of cement in volume batched concrete or mortar;

b) develops higher early strength although standard strength (28 day) may not be very different from any other cement;

c) improves workability and also causes less bleeding in mortar or concrete; and

d) requires a lesser curing period.

Cement with a greater fineness has the following disadvantages:

a) decays rapidly when left exposed to the atmosphere;

b) gives rise to higher shrinkages and greater proneness to cracking;

c) more amenable to “pack set” when cement bags are piled one above the other;

d) higher cost of grinding;

e) requires more gypsum to retard the initial set of cement which has more tricalcium aluminate available for early hydration;

f) faster alkali-aggregate reaction if such a reaction is likely with the aggregates used;

g) generates heat more rapidly during the chemical reaction; and

h) requires good initial curing.

However, it should be noted that most of the disadvantages can be overcome by greater quality control.

C.6 STRENGTH CLASSES OF CEMENT

Strength Class 52.5 cement can be manufactured or imported for a specific project under the permission of Sri Lanka Standards Institution.

APPENDIX D
SOME USEFUL INFORMATION ON ADULTERATED CEMENT

D.1 GENERAL

Most common form of adulteration is to produce underweight cement bags. The next common form is to insert warehouse cement sweepings which may be partially aerated. Less common forms are inclusion of very fine quarry dust and inclusion of hardened cement lumps in finely ground form. Every user should exercise caution in the purchase of cement and if adulteration is suspected it may be useful to inform the manufacturer/vendor.

D.2 IDENTIFICATION

The best form of identification of adulterated cement is to conduct all the tests specified in this standard. It is also possible to identify adulteration by some simple observations. Some means of identification using simple observations are as follows:

a) check whether machine stitches of cement bags are tampered with. Generally hand stitches are similar on both sides of the bag and are of inferior quality;

b) if the cement bag bends sharply when handled or transported, it is likely to have been tampered with;

c) when the bottom stitched end of the bag is pounded on the floor a few times to pack the cement, and if the bag is tampered with, the opening used for filling cement at factory (a top cover of the cement bag) will open out easily or can be seen as damaged slightly;

d) the gross mass of a cement bag is approximately 100 g to 200 g more than the net mass specified, otherwise it is likely to have been tampered with;

e) when equal volumes of cement and water are shaken in a test tube or clear glass bottle and left for a few minutes slight adulteration may show as a dark spray and heavy adulteration may show up as a precipitate; and

f) when cement is spread into a thin layer on a glass sheet and then covered with another similar glass sheet, adulterated cement may show up patches of slightly different shades of colour.

APPENDIX E

GUIDELINES FOR SELECTION OF CEMENT TYPES AS PER SRI LANKA STANDARDS

Cement type	SLS No	Strength class	(a) Normal strength concrete (grade 30 & below)	(b) Medium strength concrete (greater than grade 30 & up to 40)	(c) Concrete subjected to severe exposure condition	(a) & (c)	(b) & (c)	Pre-cast concrete	Cement based products	Rendering	Plastering	Masonry work
OPC	**SLS 107**	**32.5 N/R** **42.5 N/R**	*** ***	** ***	** **	** **	** **	*** ***	*** ***	*** ***	** **	** **
BHC	**SLS 1247**	**32.5 N/R** **42.5 N/R**	*** ***	** ***	*** ***	*** ***	** ***	** **	* *	*** ***	** **	** **
PLC	**SLS 1253**	**32.5 N/R** **42.5 N/R**	*** ***	** ***	* *	* *	* *	** **	* *	*** ***	** **	** **
MC	**SLS 515**	**22.5**	Not Recommended								***	***

*** – Strongly recommended, ** – Recommended, * – May be used under technical guidance,
BHC – Blended Hydraulic Cement, OPC – Ordinary Portland Cement, PLC – Portland Limestone Cement, MC – Masonry Cement.

NOTE 1: *Specific guidelines with respect to usage of different types of cement for concrete are given in* ***BS EN 206-1*** *and* ***BS 8500****.*

NOTE 2: *For the specific exposure condition of "concrete subject to water pressure in a very aggressive condition rich in sulphates", PLC content in the mix should be more than that of OPC, if PLC is selected.*

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AMENDMENT No.1 APPROVED ON 2016-06-23 TO SLS 1253:2015

SRI LANKA STANDARD SPECIFICATION FOR PORTLAND LIMESTONE CEMENT (Second Revision)

2 REFERENCES

In line 4, 8, 10 and 11, delete '**BS**' and substitute '**SLS**'.

3 DEFINITIONS

Delete '**3.2.1'** and substitute '**3.3**' and change the remaining clause numbers accordingly.

3.7 main constituent

In line 2, delete 'a total of'.

5.1.1 *Portland cement clinker*

Insert 'or by X-ray fluorescence (XRF) technique given in **SLS ISO 29581-2** may be used. In case of dispute, unless otherwise agreed by all parties, only the test methods described in **SLS ISO 29581-1** shall be used' at the end of paragraph 2.

5.1.2 *Limestone*

In paragraph 3, line 2 and 4, delete '**BS**' and substitute '**SLS**'.
In paragraph 4, line 2, delete '**BS**' and substitute '**SLS**'.

5.4 Additives

Delete entirely paragraph 4.
In paragraph 5, line 1, delete '**BS**' and substitute '**SLS**'.

TABLE 3

Delete entirely, Row 2 referring to 'Magnesia content'.

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