Importance of quality assurance of materials for construction work

R.Savitha
Building Materials Research and Testing Division, National Building Research Organization

ABSTRACT: Quality assurance of building materials is very essential in order to build strong durable and cost effective structures. When construction is planned building materials should be selected to fulfill the functions expected from them. The objective of this paper is to discuss the importance of quality assurance and product certification of most common building materials such as concrete, steel, aggregates, cement and building blocks in accordance with relevant standards and the long term and short term effects that would results if building materials do not fulfill the requirements.

1. INTRODUCTION

Material testing is a must in all industries, particularly the building sectors. This is because an incorrect assessment of a material would ultimately be harmful to people and the environment.

The infrastructural development of a nation, eventually leads to the prosperity and growth of that country. Utilization of high quality construction materials leads to high quality infrastructures. The quality of such materials should be assessed properly in an accepted laboratory, using standard test methods.

Building materials should be chosen to comply with the relevant standard. SLS, BS, EN, IS, JIS AS and ASTM standards are used in Sri Lanka.

SLS mark implies compliance of the material with the relevant SLS standard and the use of ISO mark is authorized after assessment of the quality management system used in the manufacturing establishment.

Construction includes the materials used in buildings, highways, bridges, railway and metro projects. The key to reliable construction and infrastructure development is the civil engineering techniques, technologies, and most importantly the building/construction materials used. Construction materials include cement, aggregate, concrete, reinforced steel, bricks, tiles, various types of composites etc. Proper assessment of the properties of these materials is vital to ensure the quality and durability of the final structure that is made with them.

Aside from structural requirements, some contractors also want to verify whether the material used in construction conform to the relevant standards.

2. COARSE AGGREGATE TESTING

In determining the quality of aggregate, the particle size distribution, specific gravity and water absorption, soundness, impact and abrasion are important factors. Impact or abrasion property is checked either in dry condition or in fully saturated condition. Soundness and water absorption are directly related with durability. It is important that the results from the soundness tests are not viewed in isolation. They should be considered with the results from the porosity and water absorption tests and the experience gained regarding them. There is a direct relation between water absorption and soundness. In general strength reduces when moisture content increases. Clay in aggregate also affects the quality of concrete produced with such aggregate.
Granite is the most common rock type found in aggregate produced in Sri Lanka. It has performed well as a raw material over many years. However from quarry to quarry the strength and other properties vary considerably and hence need frequent verification.

The particle size distribution of coarse aggregate has an influence on workability of concrete, water requirement and ability to be compacted without voids or honeycombs. Thus it indirectly affects the strength and durability of concrete. Therefore coarse aggregate meeting standard grading requirements should be used.

The maximum size of aggregate used for making concrete is limited by size of structure, reinforcement detail and method of placing concrete.

Aggregate impact value and aggregate crushing value indicate the strength or weakness of the aggregate and these two parameters are correlated to each other.

3. FINE AGGREGATE TESTING

In testing fine aggregate, particle size distribution, specific gravity and water absorption, soundness and organic impurities are important factors. Soundness and water absorption are directly related with durability. Clay in aggregate also affects the quality of concrete produced from such aggregate.

River sand is mostly used in Sri Lanka as a fine aggregate. This has performed well as a fine aggregate. Off shore sand, dune sand and crushed rock sand have been identified for use in Sri Lanka as an alternative to river sand for various building applications. It is important to test the quality of these materials before use.

4. CEMENT TESTING

Chemical properties, compressive strength of mortar prisms, fineness, soundness and setting time are important factors in testing cement. In Sri Lanka cements with SLS mark are commonly used. However, there could be batch to batch variation in properties of cement which should be checked and controlled. The chemical properties of the cement affect the ultimate performance in all of its applications. Many of the performance characteristics could be assessed by means of physical tests.

The compressive strength of hardened cement is the most important of all the properties. Therefore, cement is always tested for its compressive strength at the laboratory using standard sand and distilled water before it is used in important works. Strength tests are not carried out on neat cement paste because of difficulties arising from excessive shrinkage and subsequent cracking of neat cement. Strength of cement is determined from cement – sand mortar prisms made by mixing cement with standard sand in given proportion as specified in the standards.

The fineness is also a very important physical property of cement. Rate of hydration of cement depends on its fineness which is related to particle size. Setting time, compressive strength, shrinkage and permeability depend on the fineness of cement.

The setting time of cement used in a concrete is important to determine the free time available to transport, place and compact it.

The soundness is a very important factor to ensure that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious problems regarding the durability of structures when such cement is used. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance

5. WATER FOR MAKING CONCRETE

Usually drinking quality natural water can be used as mixing water for making concrete. However, water can be tested by making two sets of test cubes one with test water and the other with distilled water (control sample). Some water which may not be suitable for drinking may still be suitable for mixing concrete if it produces a 28 day compressive strength of atleast 90% of the control sample.

In addition to compressive strength chemical properties of the water should be checked since salt or brackish water can cause dampness of the concrete, efflorescence (white deposits of precipitated salts on the surface of the concrete), increased risk of corrosion (rust) to embedded reinforcement, damage to paint systems and reductions in strength and large variations in the setting time of concrete.

It is therefore advisable not to use such water to ensure the durability of concrete work.

Typical limits of chemicals that are acceptable in mixing water for concrete are specified in standard specifications to serve as a useful guide in practice.

6. MIX DESIGN OF CONCRETE

Mix designs are done in a standard manner in order to obtain required strength and workability with economy.

Laboratory test results of control concrete test cubes made by using different brands of ordinary Portland cement (strength grade 42.5N) same metal (20-5mm graded aggregate) and same sand (M-graded river sand) are given below: It can be observed that the use of different cement brands give rise to appreciable strength variation even with the same water:cement ratio

Table 1: Results of Laboratory Trial (i)

Quantity of cement/m^3	410kg	
Quantity of sand/m^3	730kg	
Quantity of metal/m^3	1055kg	
Quantity of water/m^3	205litres	
W/C ratio	0.50	
Test Results	**Cement Brand 1**	**Cement Brand 2**
Compressive Strength at 7-day (N/mm^2)	38.0	29.0
Compressive Strength at 28-day (N/mm^2)	44.5	39.0
Observed slump (mm)	75	65

Table 2: Results of Laboratory Trial (ii)

Quantity of cement/m^3	375kg		
Quantity of water/m^3	205litres		
W/C ratio	0.50		
Quantity of aggregates and Test Results	**Cement Brand 1**	**Cement Brand 2**	
		Trial 1	Trial 2
Quantity of sand/m^3	765kg	735kg	890kg
Quantity of metal/m^3	1055kg	1105kg	965kg
Compressive Strength at 7-day (N/mm^2)	30.5	25.0	26.5
Compressive Strength at 28-day (N/mm^2)	50.5	32.0	35.5
Observed slump (mm)	60	110	60

7. STEEL TEST

Steel test is important in order to determine the reinforcement strength and ductility.

Tensile testing is carried out under uniaxial tensile loading in order to evaluate proof/yield strength, ultimate tensile strength, % elongation and Young's modulus of reinforcing bars.

Tensile ductility of a specimen can be explained as percentage elongation at maximum force or the final elongation observed after breakage.

Area under the elastic region of the Stress Vs Strain graph gives tensile toughness.

8. CEMENT BLOCK TEST

Cement building blocks are commonly made of ordinary portland cement, sand (or a mix of gravel and sand), water and additives. The raw materials should be checked to verify that they satisfy the relevant requirements before using. Cement blocks are available in solid, cellular and hollow forms. They can be produced by hand casting or machine casting. Cement building blocks are tested in respect of dimensional requirements, compressive strength, absorption, drying shrinkage and wetting expansion and density. These properties are tested to make an assessment of the structural stability and durability.

In order to review the quality of cement blocks presently used in Sri Lanka results of tests on cement blocks performed in Building Materials Research and Testing Division of NBRO during January to October 2012 were analysed. This analysis was based on samples of cement blocks submitted for testing to NBRO by various clients. (See Tables 3 and 4)

Work sizes of the blocks were as follows:

Length- 390mm
Height- 190mm
Width- 100 or 150 or 200mm

They were cellular or solid type. Hollow type blocks were not submitted for testing.

Table 3: Compressive strength test of cement building block

Compressive strength requirement (SLS 855- non- load bearing blocks)	Average≥1.2 N/mm^2 Minimum≥0.9 N/mm^2
Number of sample tested	21
Number of sample passing average and minimum requirement	16
Number of sample failing minimum strength requirement only	04
Number of sample failing average and minimum requirement	01

Table 4: Dimensional requirements of cement building block

Dimensional requirements	Atleast 18out of 20 Nos of blocks should satisfy the length, width and height requirements
Number of samples tested	08
Number of samples passing	04
Number of samples passing Shell and web thickness and volume of cavities for cellular blocks	08

Requirement for absorption is specified as a maximum limit of 240kg/m^3. All the samples tested satisfied this requirement.

For all the cellular blocks tested block densities were in the range of 1150 to 1800kg/m^3 and concrete densities were in the range of 1700 to 1900kg/m^3

For all the solid blocks tested block densities were in the range of 1900 to 2100kg/m^3 (Average 2000kg/m^3)

The strength requirements specified for cement blocks in SLS 855 is based on a typical building design in which the densities of blocks were taken as 1500kg/m^3 for hollow blocks and 2000kg/m^3 for solid blocks. The average density observed in the study for solid blocks was the same as that given in the standard specification.

SLS 855 states that the block density normally falls within 1000kg/m3 and 2800kg/m^3 and the observed test results were well within this range.

9. TESTING OF FIBRE REINFORCED COMPOSITES

Brittle materials are stronger than ductile (metallic) materials. Ductile materials are tougher than brittle materials. Ductile materials deform plastically under tension. Brittle materials hardly exhibit plastic deforemation (maximum of upto about 10% plastic strain) under load. Under a light load brittle material deflects less than ductile materials since they are more rigid. Under a heavy load brittle materials break but ductile materials merely bend. A material that is rigid is not necessarily strong and is often found to be brittle.

Rigidity (Stiffness) is a measure of a material's ability not to deflect under an applied load. The area under the elastic curve on the stress-strain diagram is a measure of stiffness. The larger the area, the higher the stiffness.

Tensile Young's modulus (E) is also related to the rigidity of the material. The higher the value of E for a material the higher the stiffness.

Ductility is the amount of plastic strain that a material can withstand before fracture in tension.

Brittle materials are quite strong in compression and are often weak in tension. Therefore, they are only tested under compression load. These materials cannot be tested under tension, because small cracks oriented perpendicular to the direction of the applied tensile force propagate to cause failure at very low stresses. The crack size varies from samples to sample and stress values show a large scatter. Test samples often tend to break at the grip of the testing machine.

Composites are strong and tough materials. A fibre reinforced composite made from brittle materials could have high toughness as well as high tensile strength. Ductile fracture usually occurrs due to overall yielding, fatigue due to fluctuating of stress and creep due to high temperature or continuous constant loading for a long duration. Failure of materials very often (95%) occur due to fatigue. Important tests on composites are tensile strength, compressive strength, bending strength, shear strength and relevant Young's Modulus. Composites are anisotropic materials (Properties depend on the direction). Therefore, test samples should be prepared by taking the directional properties into consideration. Usually any property in an anisotropic material is expressed in relation to two orthogonal directions. Eg. Tensile strength parallel to the direction of fibres and the strength in the direction perpendicular to it.

10. CONCLUSION

Testing for quality of construction materials is very important. Objective of testing construction materials is to provide an assurance to the user on the reliability of the materials. Thus, construction materials testing laboratories make a useful contribution to national development through the estimation of the quality of construction materials.

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