Use of Indian Laterite as a Sustainable Construction Material: A Review

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Abstract- *Laterite has been used in construction since a very long time especially in India,it was also first identified in India by Dr. Francis Hamilton in 1807 but has been used indigenously much before that, there is great regional variation in Indian laterite as they occur usually with other minerals like bauxite. This variation in properties has led to different uses for laterite in different parts of the country. In the construction industry there is again great diversity In the uses of laterite, in eastern India these are used in cement manufacture while in south and western India these are used in low level construction and masonry. In other parts of the world laterite has been used as road metal and as aggregate substitute but the lack of consistency in properties and proper standardization of manufacture processes as well as a comprehensive building code does not exist in India, IS 3260-1979 serves only as a rough guide for masonry blocks which itself has been reviewed by experts and improvements have been recommended, This paper aims to summarize the properties of different types of laterites found in India, their uses in construction and comparison and deviation of properties from IS 3620-1979,further there has been lab testing of the properties of Konkan laterite and coarse aggregate of 20 mm and fine aggregate made from Konkan laterite in accordance with IS standards.*

Keywords- Laterite,Laterite aggregate,Konkan laterite

I. INTRODUCTION

Laterite is a reddish brownish rock found mostly in tropical belts of the world. Prolonged processes of chemical weathering which produce a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils.The tendency to indiscriminately use a wide array of terms to describe laterite, irrespective of the geotechnical characteristics and related engineering behaviour of the material, has caused much confusion amongst practitioners

Some names of laterite are

- Brickstone-India
- Cabook-Sri lanka
- Murram-East Africa
- Eisenkrutse –Germany
- Plinthite-USA and South africa

The majority of the land area containing laterites is in between tropic of Cancer and Capricorn.The term “laterite” was first used was originally used for highly ferruginous deposits first observed in Malabar Region of coastal Kerala and Dakshin Kannad & other parts of Karnataka. It is a highly weathered material, rich in secondary oxides of iron, aluminium or both. It is either hard or capable of hardening on exposure to moisture and drying.

Numerous monuments including prehistoric megaliths of Kerala and world heritage sites of churches of Goa, India, third generation Angkor temples or walls in Group G monuments of My Son, Vietnam are made of laterite.

1.1 OCCURRENCE

Laterite occurrences are widespread in India. Major share of about 87.5% resources was distributed in two states namely Madhya Pradesh (61%) and Rajasthan (26%). The remaining 13% of resources are spread over in the states of Andhra Pradesh, Kerala, Gujarat, Maharashtra and Jharkhand

Andhra Pradesh was the leading state in laterite production contributing 77% of the total production, followed by Madhya Pradesh (11%), Karnataka (5%) and Gujarat (3%). The remaining 4% was contributed by Kerala & Maharashtra

1.2 USES

Laterite is used widely as a road metal and as a local stone for culverts and buildings it is used for construction of light structures, partition walls, boundary walls, etc. Laterite as a building stone possesses one advantage that it is soft when quarried and can be easily cut and dressed into blocks and bricks which on exposure to air become hard.

The industrial use of laterite is in the cement industry. It is used as an additive for lowering the clinkerisation temperature and supplementing aluminous and iron contents required in the manufacture of cement.

1.3 GENERAL PROPERTIES

The mineralogical & chemical composition of laterite depends on their parent rock. Lateritic soils are found in a variety of red, brown, and yellow, fine grained matrices with nodular gravels and cemented soils, whose cohesiveness may vary from being loose materials to dense granules. Their colors are caused by presence of iron and aluminum oxides or hydroxides in the soil matrix. When such soils are exposed to the atmosphere the iron hydroxides lose the moisture quickly to form iron oxide which develop a good bond with other particles in soil to form concretionary laterite.

II. IS 3620-1979

The code deals with use of laterite blocks in masonry however it recognizes that there is too much regional variation in laterite, hence lays down the following parameters for laterite building stone.

Table 1 Specifications for laterite (IS 3620-1979)

Characteristic	Requirement	Test method
Water absorption	not more than 12% by mass	IS 1124-1974
Specific gravity	No less than 2.5	IS 1124-1974
Compressive strength	Not less than 3.5 N/mm^2	IS 1124-1974 (part 1)

Table 2 specifications for masonry block (in millimeters)

length	breadth	Thickness
390	190	190
490	290	190
590	290	290

2.1 REFORM OF IS CODE

As concluded by Krishna R Reddy & Venkat Reddy (May 2015) the specimen sizes are too unwieldy to handle and prepare as prescribed by IS3620-1979 and suggests different size of test block or usage of brick sized specimen.

Further it suggests that since there is variation in not only strength of different laterites but as well as function it suggests a classification system similar to that of bricks (class A, class B,class C) based on functions well as properties.

III. CLASSIFICATION OF INDIAN LATERITES

3.1 MALABAR LATERITE

The Malabar region consists of northern part of Kerala State, located in west coast of India

Laterite stone blocks are being used as prime material for architectural applications in Malabar region of western India for ages, because of being abundant, relatively easy to cut and shape and showing good performance in many applications. The midland region of Malabar is well known for occurrence of laterite and almost 60% of the state of Kerala is covered in laterite. The special significance of malabar to laterites is that it was here that Dr. Francis Buchanan-Hamilton, a professional surgeon, gave the first account of this rock type, in his report of 1807, as "indurated clay", ideally suited for building construction

There has been great study into properties of Malabar laterite and it is one of the few regions where laterite is used but also investigated and documented with respect to its properties as a building material.

In a 2012 study (Kasturbha A.K,NIT Calicut) a detailed investigation of laterite profiles was done from a number of quarries in Malabar region, The hard ferruginous vermicular laterite, dark reddish brown to red colour, occurs in the top portion of the profile, possesses high strength, specific gravity and low water absorption. This top portion of laterite, found to possess less clay content (yellowish white to white colour), can be categorised as good quality for building purposes. Specific gravity and compressive strength decrease with depth. The increase in water absorption of specimens with depth is seen in all laterite profiles. This may be attributed to the increase in clay content (Kaolinite) with depth as identified by the megascopic study of the specimens presented below .The decrease in strength and increase in water absorption with depth leads to a decline in the quality of laterite blocks of the deeper layers

Depth (m)	Megascopic Study	
	Image Analysis	Remarks
1.8		Dark brown to dark red, with yellow colour lining in the cavities
3.0		Dark red to brown ferruginous materials filled with yellowish white clay
5.2		Red to pink streaks of iron minerals in a matrix of kaolinite mainly white and light yellow in colour

Analysis of laterite layers (Kasturbha A.K,NIT Calicut)

Block testing was also done on Malabar laterite in accordance with IS 3620-1979 and sample size of 390x190x190 as well as Crushed aggregates passing through 40 mm and retained in 20 mm Indian standard sieve were used to determine physical properties.

The conclusions for Malabar laterite reached is summarized as

1. It contains lot of structural irregularities in the form of cavities and pores
2. The Malabar laterite can be categorized as weak rock (weaker than class B bricks of minimum strength 3.5 MPa) that can be used for low-rise buildings and partition walls.
3. Compressive strength and specific gravity of laterite blocks decreases with the depth of quarry. The increase in water absorption of laterite samples of the deeper layers may be attributed to the increase in clay content
4. Laterite of relatively good quality for building purpose (high compressive strength and low water absorption) was located in the top portion of profiles

Summary of properties of materials taken from four quarries
UL- Ulikkal,
PTA-Panayathamparamba
MU- Muchukunnu,
PM- Perinkulam

Results have been only taken for top of the profile (depth 1-1.8m) as this is preferable stone for building construction.

Table 3: properties of Malabar laterite

Property	IS3620 1979	UL	PTA	MU	PM
Specific gravity	>2.5	2.15	2.67	2.71	2.95
Compressive strength	>3.5 N/mm^2	1.44	2.42	2.06	3.06
Water absorption	Not more than 12%	10.82	9.74	12.8	9.12
Hardness moh scale	-	1-2	3-4	1-3	3-4

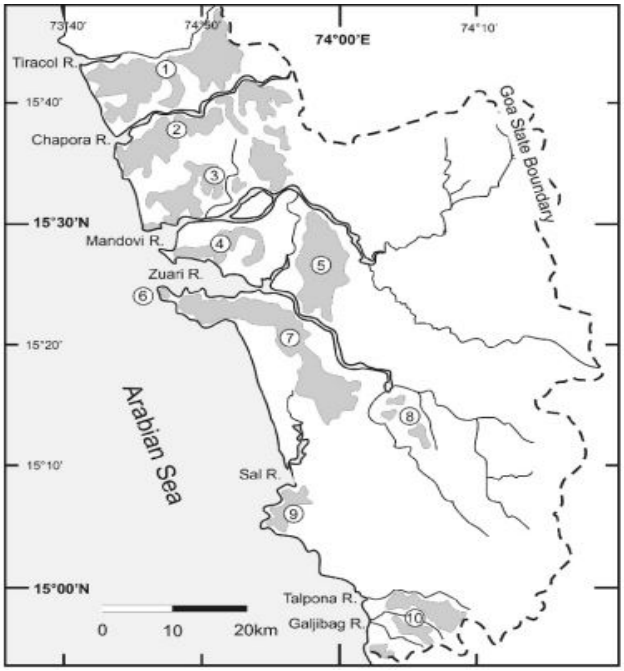
Further studies on compressive strengths of Malabar laterite as well as nearby regions were compiled by K.Reddy and V.Reddy in 2015 have been presented below

Table 4: compressive strength of western Indian laterites

Quarry location	Published by	Compressive strength(Mpa)
Kannur	GEC Kannur Santosh & Beena 2012	0.55-3.35
Goan laterite	IIT madras	3.54-5.06
Mangalore	NIT Karnatka Sujatha et al 2011	1.81-4.83
Areecode	NIT Calicut	4.26-10

3.2 GOAN AND KARNATAK LATERITE

Nearly two third of the area of Goa is covered by a mantle of laterite ranging in thickness from a couple of meters to over 25 mts. Maximum thickness of laterite is observed along the coast in the west and minimum along the Ghat section in the East. the laterites in Goa are generally formed from Quartz-chlorite-Amphibole Schist, Pink ferruginous phyllite, Schitose metabasalt & Metagreywacke.



Map of distribution of key laterite-capped table-land (plateau) regions of Goa. 1, Pernem Plateau; 2, Mapusa Plateau; 3, Porvorim Plateau; 4, Panjim Plateau; 5, Ponda Plateau; 6, Vasco de Gama Plateau; 7, Dabolim – Madgaon Plateau; 8, Quepem Plateau; 9, Cabo de Rama Plateau; 10, Canacona Plateau.

The laterite in Goa are used in construction activity as laterite boulders and laterite stones (Locally called as

"chira").In Goa the laterite blocks are usually grouted and then cemented or plastered over and painted.

They are a constant feature In Goan architecture because of its aesthetic properties as well as beinglocally abundant and cheaply available, it is also well suited for the harsh Goan monsoon and hence laterite has its main applications in exterior cladding in old colonial style bungalow for testing of engineering properties of goan laterite (Sutapa Das ,11 DBMC 2008) testing was carried out at Patradevi quarry at north Goa for a profile study and qualitative strength tests.

The visible laterite zone was about 9m deep appeared as a uniform brick wall without any significant variation. However, a close inspection revealed patches of salt, clay, quartz and iron which may lead to efflorescence, water absorption, hardness and staining respectively

Table 5: Properties of Goan laterite (Patradevi quarry)

properties	IS3620-1979	Goan laterite
Water absorption	Less than 12 % by mass	11.45 %
Specific gravity	No less than 2.5	2.25 (apparent)
		3.06 (true)
Compressive strength	Not less than 3.5 N/mm²	5.05 N/mm²
cappilarity	-	1641 g/m² / min0.5
porosity	-	25.75%
Flexural strength	-	1.23 N/mm²

Conclusions drawn from study of Goan laterite
(Sutapa Das ,11 DBMC 2008)

This indicates that laterite is a weak stone, even weaker than good quality brick [IS 1077]. This value is much lower than the calculated average strength of 10.3MPa found from rebound hammer test, In spite of high content of strength-giving iron oxide, Goan laterite is weak in compression and flexure even compared to standard brick.

Karnataka laterite

Studies have been carried out on laterite sand in Karnataka for use as replacement of fine aggregates in concrete.

Lateritic sand which was used as fine aggregates of size 4.75 IS sieve was found at Hankuni, 7km from Humnabad Its properties compiled by Amar R Dongapure (IJERT 2014) are

Properties	Laterite sand
Specific Gravity	2.78
Bulk Density	1.66 (compact) 1.49 (loose)
Water Absorption	4 %

3.3 KONKAN LATERITE

This laterite was obtained in the form of scrap and waste blocks from dapoli region in Maharashtra state of India,the size of most blocks was 390x19x19 according to IS specifications but many were irregular shaped scrap blocks.
Laterite blocks have also been used in construction of residences and exterior walls in this region of India since a long time,there are also many quarries operating within the district,we obtained the scrap material from one supplier and performed tests on it to ascertain its engineering properties,the blocks were broken by hand into aggregates passing through 20mm IS sieve and retained on 12 mm IS sieve,the left over scrap was converted into fine aggregate passing through 2.36mm IS sieve and retained on 1.44mm IS sieve and silt was passed through 90 micron sieve.

Investigations done of soil in interior of maharshtra in Talmud,near osmanabad have found the following properties for the laterite available there "The Laterite has average thickness of 5 to 10 meters. The Laterites appear more ferruginous in nature rather than aluminous.

The Laterite formation is demarcating 620 meters level as the limit of Lateritisation, as below this level Laterites are not seen, The Basaltic Laterites are formed by extensive chemical weathering of Basalts during a geologic period (Cliff and 2008). Percolating waters caused degradation of the parent Basalt and preferential precipitation by acidic water through the lattice left the iron and aluminum composition with clay being found with the lower basalt levels," however studies performed on agricultural lands in Dapoli area have concluded that the laterite in that area has more sand content than clay content.

The properties of dapoli laterite under laboratory conditions can be summarized as below

Table 6: properties of Dapoli laterite

Properties	IS 3620-1979	Laterite coarse aggregate	Laterite fine aggregate
Water absorption	Less than 12 % by mass	8.4%	14%
Specific gravity	No less than 2.5	2.74 (E.g method)	2.6
		2.4 IS method	2.24
Compressive strength	Not less than 3.5 N/mm²	2.35 N/mm² For whole block	
elongation		11.96%	-
flakiness		1.3%	-
Crushing value		34.8%	-
Fineness modulus			3.2

Compression testing of Konkan laterite

Breaking & sieving of Scrap laterite blocks to make aggregates

20mm laterite coarse aggregate created

IV. USES IN CEMENT INDUSTRY

Major share of laterite about 87.5% resources is located in two states, namely, Madhya Pradesh (61%) and Rajasthan (26%).However Andhra Pradesh was the leading state in laterite production contributing 75% of the total production, followed by Madhya Pradesh (15%),

In the states of Rajasthan and Andhra Pradesh the laterite is usually not mined in block form for building purposes but instead it is used as an additive in the cement industry. “Gradewise analysis of production in 2013-14 revealed that the bulk of production was of Cement grade, i.e., 97% of the total production during the year.”-Indian minerals yearbook 2013-2014.

It is used as an additive for lowering the clinkerisation temperature and supplementing aluminous and iron contents required in the manufacture of cement. It is also reported that laterite is capable of removal of phosphorus from solutions and percolating columns of laterite remove cadmium, chromium and lead to very low concentrations. The industrial end-use consumption of laterite in 2011-12, 2012-13 and 2013-14 was approximately 3.89 million tonnes, 4.37 million tonnes and 4.45 million tonnes, respectively the consumption of laterite in cement has scaled up due to increased demand of cement in the country,Laterite is also added as it is a more sustainable material as noted by Syed Zaighum Abbass (Laterite as Supplementary Cementing Material (SCM) to Reduce Greenhouse Gas Emissions, 2012) a 1% reduction in energy and co2 emmisions was observed for every 1 % replacement of clinker and the performance of laterised cement was found to lie between that of limestone and fly ash cement blends.

Table 7 : State wise use in Cement Industry

state	Used in cement industry (in tonnes)
India	1003882
Madhya pradesh	487142
Kerala	432292
Gujarat	29524
Karnatka	14018
Maharashtra	8872
Tamil nadu	85

V. COMPARATIVE SUMMARY OF PROPERTIES

Table 8: Summary of engineering properties of laterite from different parts of India

Properties	IS 3620-1979	Malabar (Kerala)	Goan Laterite	Konkan laterite (Maharshtra)
Water absorption	Less than 12 % by mass	9.12-12.8	11.45	8.4
Specific gravity	No less than 2.5	2.15-2.95	2.25 (apparent) 3.06 (true)	2.74 (E.G method) 2.4 (IS method)
Compressive strength	Not less than 3.5 N/mm²	1.44-3.06 N/mm²	5.05 N/mm²	2.35 N/mm²
Hardness (moh scale)	-	1-4	-	-
capillarity	-	-	1641 g/m² / min0.5	-
porosity	-	-	25.75%	-
Flexural strength	-	--	1.23 N/mm²	-
elongation	-	-	-	11.96%
flakiness	-	-	-	1.3%
Crushing value	-	-	-	34.8%

VI. CONCLUSIONS

Laterite shows great potential as a sustainable alternative to conventional building material with 2.83 cum of scrap generated for every 11.3 cum of laterite extracted, there is plenty of waste material to utilize as well, since laterite has been used for a long time the usual logistical challenges of introducing a new material will not be faced as there is already a vast network of mines, suppliers, workers, craftsmen familiar with laterite stones.

The greatest challenge is in the regional variation of properties hence further study has to be carried out to classify Indian laterite with respect to engineering properties, As seen above the laterite from Konkan region is suitable for use in concrete as well as the laterite from other regions. The

opportunity offered by this regional variance of properties is that the laterite is well suited for use in its native climate and that it can be put to different uses in different place for example some laterites can be used to make unpaved road or serve as road metal while other can be used for masonry.

Another point that has to be raised is the reform of IS 3620-1979 to include not just masonry related standards but also to inculcate details for more types of laterite, different block sizes, as well use of laterite as aggregates.

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