The Clarion Volume 11 Number 1 (2022) PP 34-47

The Clarion

International Multidisciplinary Journal

ISSN : 2277-1697

CELEBRATING 10 YEARS OF THE CLARION

Review of green building movement and appraisal of rating systems in Indian context.

Sunita Bansal[1], Srijit Biswas[2], S. K. Singh[3]

1. Department of Civil Engineering, FET, Manav Rachna International Institute of Research and Studies, Faridabad, India
2. Department of Civil Engineering, FET, Manav Rachna International Institute of Research and Studies, Faridabad, India
3. Department of Environmental Engineering, Delhi Technological University, Delhi, India

Abstract

Mounting issues of resource scarcities and socio-economic development demands sustainable development in the construction sector. Architecture, Engineering and Construction industry though incohesive, but is undergoing profound transformation by adopting Green Building guidelines. With roughly 17.2% of the world's total populace and an urban populace of 372 million (bigger than the whole US populace), India faces mammoth task. India has two programs: LEED-India and GRIHA which are in their nascent stages and need to be appraised. This study presents a brief background of Green Building evolution and an objective summary of LEED-India and GRIHA mapped to proven rating tools US-LEED and BREEAM. It also examines how structural impacts are addressed and how structural engineers, as being one of the stakeholders of Integrated Design Team, can contribute to assessments through sustainable construction. In the end, the probable criterions to be included in the GBRS for the sustainability of structure design are also discussed.

Keywords: US-LEED, BREEAM, GRIHA, LEED-India, Sustainable Structure design.

1. Introduction

Universally, buildings utilize large resources, devour roughly 40% of all energy and create 39% of GHG emissions in the United States (wbcsd, 2016). In addition, structures are in charge of more than 10% of the world's freshwater withdrawals and 25% of wood harvest globally (Kibert, 2007). These discoveries legitimize the squeezing and timely engagement of the Architecture, Engineering, and Construction (AEC) industry in endeavors towards sustainable development protecting world's assets and advancing quality life over the globe.

Sustainable construction is "a holistic process starting with the extraction of raw materials, integrated planning, design, and construction of buildings, along with their demolition and management of the resultant waste" (Sjostrom & Bakens, 1999). It was encouraged to adopt civil engineering practices vide six basis of sustainable construction: "minimize resource consumption; maximize resource reuse; use renewable or recyclable resources; protect the natural environment; create a healthy, nontoxic environment; and pursue quality in creating the built environment" (Kibert, 2007). Although the terms "Sustainability" and "Green" are often used interchangeably in the AEC industry, going 'Green' distinguishes itself from 'Sustainability' in that conceptually it balances precariously on one leg of environmental health of the sustainability tripod-Economic vitality, environmental health, and social equity. The vocabulary of greenness allows the environmental activist to focus on a narrower agenda for change while leaving in abeyance the more politically sensitive and upsetting social equity and economic vitality. Following the UN declaration of 1990-2000 as International Decade for Natural Disaster Reduction and the mid-term review

Corresponding author : sunitabansal221@gmail.com
DOI: 10.5958/2277-937X.2019.00001.7

at Yokohama in 1994, stakeholders emphasized a paradigm shift to disaster prevention, mitigation and preparedness than disaster response. AEC industry attempts to address the sustainability "triple bottom line" by developing guidelines for Green Buildings design and construction not limited to resource efficiency confirming economic and environmental aspects but is being expanded to disaster resilience which has social implications also (Pongiglione M. C., 2016).

This can be seen as a result of Hyogo Framework of Action 2005-2015 that focused on versatility of structures to disasters with three primary objectives of coordinating Disaster Risk Reduction (DRR) being developed, reinforcing establishments and including DRR in readiness, reaction and recuperation. The five essential activities include making DRR as a national priority with a solid institutional base for execution, distinguishing, evaluating and observing disaster dangers to inculcate a culture of security and strength at all levels (Horekens, 2007). Following this Hyogo structure, Sendai framework for DRR 2015-30 was embraced by 187 UN part states in March, 2015 in Japan, India being one of the signatory. The Sendai Framework is the principal agreement of the post-2015 improvement plan, with seven targets sketching out resilience enhancement by readiness and usage of present day designing, construction laws and norms and timely vulnerability reduction (Jibiki, 2016). In this way DRR is the contemporary issue for the legislatures to accentuate upon.

Since India is a developing country with highest density of population and growing urbanization, the sustainability of construction sector in India cannot be ignored. India has adopted LEED-India and GRIHA but they are in their nascent stages of implementation need to be compared to BREEAM and US-LEED and need to be inclusive of sustainable structure design parameters.

This paper covers three aspects. Firstly, this study will discuss the background of Green Building Movement and major features of the rating systems of "Green building" practiced in USA, UK and India. This will include an analysis of the key points of each system. Second, this paper will benchmark and compare Indian Rating systems (LEED-India and GRIHA) to those in USA (LEED) and UK(BREEAM). And thirdly, a desk-based research has been carried out to parametrically investigate-what the ratings schemes measured in terms of structure, how structural engineers can contribute to the sustainability of buildings as a member of a multidisciplinary team and how much of the sustainability of a building was attributable to its structural aspects. In the end, it is aimed that a comprehensive understanding of the two rating systems will be reached at through this exploratory study.

2. Literature review

Many developed and developing countries like U.S., U.K., Australia, Canada, Japan, Korea and India have either as of now obligatorily adopted the Green Building framework or are embracing them. The U.K. was the first to make solid strides towards this path and set up BREEAM in 1990, the primary green building rating framework. The United States Green Building Council (USGBC) at that point propelled the Leadership in Energy and Environmental Design (LEED) rules in the year 2000. Many developing countries, such as India, also established their Green Building Councils and adopted guidelines in their country's context. Evolution of the Green Building Rating Systems (GBRS) can be attributed to many international comparative studies as part of the sustainability movement (Wu & Low, 2010). Yukihiro KAWAZU et al (2005) in the World Sustainable Building Conference, Tokyo compared the assessment results of BREEAM, LEED, GBTool, and CASBEE. Inbuilt ltd. (2010) published a white paper in the year 2010 covering the history, facts and features of BREEAM and LEED, their credits and weightings. A comparison, overlaps and the conclusions about each scheme's benefits in UK's context was also presented. Rezaallah, Bolognesi and Khoraskani (2012) compared BREEAM Offices 2008 and LEED-NC categories' priorities and importance and the process of certifying a building. Hamedani and Huber (2012) directed a relative investigation of LEED, BREEAM and DGNB certification frameworks in urban sustainability. Pongiglione Pongiglione and Calderini (2016) exhibited a cutting edge extensive literature survey and an investigation of 36 GBRS dissected from sustainable structure outline point of view. A few investigations have concentrated on the inspirations, hindrances and difficulties to executing green building implementations. Haapio and Viitaniemi (2008) dissected and classified existing tools, contrasts between various tools and underscored that notwithstanding ecological perspectives, sustainable building incorporates economic and social angles. There being many more studies comparing LEED, BREEAM and other international GBRS but no significant studies have been conducted in the Indian context which appraise the

green building programs followed in India. India has 53 urban zones with populaces more prominent than one million. The three most populated metropolitan urban communities – Mumbai, Delhi and Kolkata have an expected populace of 18 million, 16 million and 14 million respectively (NOTES FOR CONTRIBUTORS, 2011). With roughly 17.5% of the whole world's populace and an urban populace of 372 million (bigger than the whole US populace), India faces amazing difficulties identified with urbanization. India as of now has LEED-India got from US-LEED and indigenous GRIHA created by TERI and received by Indian Ministry of New and Renewable Energy. Potbhare, Syal and Korkmaz (2009) exhibited a survey of Green Building Movement Timelines in Developed and Developing Countries including India to fabricate an International adoption structure. Elnokaly and Vyas (2014) examined the sustainability assessment for new buildings within BREEAM-U.K., US-LEED and GRIHA-India and stated that there should be country context assessment of the socio economic factors. Sustainable structure design was however not considered in the study. It has become important to evaluate the performance of rating systems because governments' incentives and policies for environment consciousness are getting associated with the rating achieved. Governments are planning regulatory obligations and are undertaking initiatives to encourage rating of buildings and to take the movement forward. This makes performance based assessment of the GBRS utmost important to ensure delivery of stated objectives.

Many studies have been conducted on the importance of Sustainable Structure design and the role of structural Engineers in achieving sustainability. It was emphasized that civil engineers and architects are responsible to alleviate the effect of building structures following holistic approach in a report for the diary of the International Association for Bridge and Structural Engineering (IABSE) (Maydl, 2004). The contribution of efficient structural frames to energy use in places of business is assessed to be around 20% of a building's embodied energy (EE) (Cole & Kernan, 1996). Sarkisian and Shook (2014) featured structure's carbon impression, structures' operational carbon impression versus its aggregate carbon impression. While an extensive assemblage of writing has explored energy utilization and CO_2 discharges identified with the building part, there are few distributed insights on impacts related principally to structural frameworks. Additionally, while analysts in the field of SSD do recognize the effect of basic frameworks and those because of rest of the building, the vast majority of the reports and measurements don't and these data are often not latest. In India, 14.5 MT of Construction and Demolition squander out of aggregate 48MT of aggregate strong waste is generated (Pappu, Saxena, & Asolekar, 2007). This immense measure of C & D waste requires to experience a conversion when the waste gets converted to a resource. Climate change adaption and Disaster Risk Reduction are certain other sustainable structure design strategies to be followed to have holistic sustainability. Sustainable structure design aspect has not been given due credits in both LEED-India and GRIHA, which needs to be investigated.

3. Certification Systems overview Green building initiatives in UK

The primary Earth Summit was held in 1972 in Stockholm, Sweden on the international front in which 113 nations had taken part and it was decided to review the advancements at regular intervals. The meeting included 26 principles of the Declaration of the UN Conference on the Human Development, an activity plan on the Human Environment and an Environment Fund (McManus, 2014). The Association for Environment Conscious Building (AECB) promoted sustainable structures in the UK since 1989. The UK Building Regulations had characterized necessities for protection levels and different parts of maintainability in building development. Work on making BREEAM started at the BRE in England, UK in 1988, and the first version for evaluating new places of business was propelled in 1990. Further adaptations for different structures including superstores, mechanical units and existing workplaces took after. In 1998, there were real changes made in BREEAM Offices standard, and the plan's format, with highlights, for example, weighting for various sustainability issues. A rendition of BREEAM for new homes called Ecohomes was propelled in 2000. This plan was later utilized as the premise of the Code for Sustainable Homes, which was produced by BRE for the UK Government in 2006/7. Worldwide renditions of BREEAM were likewise propelled. Another significant update in 2011 brought about the dispatch of BREEAM New Construction, which is currently used to survey and confirm all new UK structures. It is a widely utilized environmental appraisal strategy for structures, setting the best practice standard for sustainable building plan in the UK, Europe and additionally the Middle East. The UK

Green Building Council (UKGBC) is a United Kingdom enrollment association, shaped in 2007, which missioned to 'fundamentally change' the built environment in the UK, the manner in which it is arranged, designed, developed, maintained and operated. The association was propelled on February, 2007 in light of the 2004 Sustainable Building Task Group Report "Better Buildings - Better Lives". The report recommended the UK Government should "review the advisory bodies concerned with sustainable buildings to simplify and consolidate them and to provide clear direction to the industry" (Seager, 2007).

BREEAM

Rating of a building by the BREEAM framework is finished by an underlying self-appraisal which depends on the performance of the building in every class recorded and afterward the scores of every classification are approved by an authorized BREEAM assessor. The foreordained weighting of every class, empowers the credits to be included to deliver a general score out of 100%. This enables certification to be granted by the Building Research Establishment. BREEAM rates all structures to be appraised irrespective of the last score ((BRE), 1990).

Green building initiatives in the U.S.

The book "Silent Spring" by Rachael Carson in 1962 had begun an across the country discussion and open mindfulness on the unlimited utilization of the Dichlorodiphenyltrichloroethane (DDT) and other harmful pesticides by the administration. OPEC oil ban of 1972 laid by the Organization of Petroleum Exporting Countries (OPEC) on the U.S. conveyed into spotlight the need to monitor exhaustible natural assets. The ban however went on for a half year yet it featured the requirement for energy security. The administration then issued tax breaks for advancements of alternative sources of energy, and made individuals mindful to diminish the undesirable utilization of oil. The U.N. General Assembly made the World Commission on Environment and Development in 1983 to address the crumbling of the human environment and natural assets characterizing sustainable advancement in their report "Our Common Future" (Brundtland, 1987). Sustainability was tended to by the U.S. government by perceiving construction sector as one of the significant consumer of the energy assets and responsible for green house gas emissions (Kibert, 2007). U.S. Green Building Council (USGBC) was then settled in 1993. The council framed the most apt and broadly acknowledged benchmark plot " Leadership in Energy and Environmental Design (LEED)" in 1998 to rate the greenness quotient of various structures.

LEED

LEED (Leadership in Energy and Environmental Design) was produced in 1998 as an accord based building rating framework by the United States of America (USA) Green Building Council (USGBC). It gives third party check of the plan and uses procedures for enhancing execution of five primary classifications of Sustainable Site, water efficiency, energy and atmosphere, materials and resources and indoor air quality. Every classification has a separate weighting by way of credits appointed to that specific class with additional credits to innovation and provincial needs. LEED USGBC got accreditation as a benchmarks developer by ANSI in 2006 (USGBC).

Green building initiatives in India

India's awesome good pioneer Mohandas Gandhi broadly stated, "There is sufficient on Earth for everyone's need, but insufficient for everyone's greed". Gandhi's vision is being put under a magnifying glass as at no other time as the world is hitting worldwide cutoff points in its utilization of natural assets. India's drives to energize sustainability were in light of the International occasions, for example, the OPEC oil ban, the Brundtland Commission or the Second Earth Summit (Bhatt & Macwan, 2012) and the acknowledgment of the green building rules by the corporate segment. Organizations like Indian Green Building Council (IGBC), TERI – Business Council for Sustainable Development (BCSD), and the Bureau of Energy Efficiency (BEE)(IGBC 2007, TERI 2007) were built up. Environmental (Protection) Act was passed in the Parliament (1986) and the Indian Parliament started a willful eco-naming project known as the "Eco-Mark" under Ministry of Environment and Forest (MoEF) and Central Pollution Control Board (CPCB). Construction Industry Development Council was framed as a nodal organization between the administration and the construction business to address the issues of ecological mindfulness and law authorization in the construction segment (1996). Indian Green Building Council (IGBC), TERI – Business Council for Sustainable Development (BCSD), and the Bureau of Energy Efficiency (BEE) spearheaded selection of Green Building rules in the nation.

LEED- India

LEED- India rating system, a private initiative but indigenized, adopted by Indian Green Building Council in 2001 as an offshoot and adaptation of the United States Green Building Council (USGBC). It alludes neighborhood principles/standards National Building Code rules for Erosion and sedimentation control, rain water collecting, wellbeing for laborers amid construction, Energy Conservation Building Code 2007 (ECBC), Environmental Information System (ENVIS), Wet lands preservation. Global standards / codes are considered wherever Local codes / standards were not available (IGBC).

GRIHA

GRIHA (Green Rating for Integrated Habitat Assessment) is a quasi-public, indigenous system developed in the early 2000s and available for project certification in 2005 for promoting sustainable building practices and techniques in India. Ministry of New and Renewable energy (MNRE), GoI has adopted GRIHA as a national rating system mandatory for all government buildings to get minimum 3-star rating for funding support and offers incentives like increased FAR. The points assigned to different criteria based on current resource priorities of India divided into various sections as: Site Planning, Energy, Occupant Comfort and Well Being, Water, Sustainable Building Materials, Construction Management, Solid Waste Management, Socio-Economic Strategies, Performance Monitoring and Validation (TERI, 2007). These variables are not quite the same as LEED principles and are customized to the Indian setting. GRIHA energizes advancement of building configuration to decrease regular energy consumption and further improve energy performance of the building inside indicated comfort limits. A building is surveyed on its anticipated functioning over its whole life span from initiation through operation (TERI, 2007).

4. Comparison of rating systems in context of India

An "apples-to-apples" examination of the affirmation frameworks is testing since every one of them have a solitary objective of sustainability. Every one of the plans depend on a rating arrangement of gathering credits that applies to an extensive variety of building composes, both new structures and existing structures. The salient features of the four GBRS are tabulated in table 1.

Table 1: Details of rating systems

Parameter	BREEAM	LEED	LEED-India	GRIHA
Country	U.K.	U.S.A.	India	India
Population(% of total world population	4.5%	0.89%	17.13%	17.13%
	15%	17%	32.7%	32.7%
Population under poverty line (Varghese, 2016)	6.1%	0.16%	2%	2%
	39%	13%	19%	19%
Land area(% of total world area)	1990	1998	2006	2007
Land under forest (Bhat, 2005), (US Forest Service, 2011)	•	•	•	•
Date Introduced	Communities• Infrastructure• New Constructions• In-Use• Refurbishment &Fit-out	New Construction and Major Renovations (NC)• Existing Buildings: (EBO&M)• Commercial Interiors• Core & Shell• Schools• Retail• Healthcare (pilot)•	New Construction • Core and Shell • Commercial Interiors (CI)• Existing Buildings: Operations and Maintenance (EB:O&M)• Neighborhood Development (ND)• Homes	GRIHA Precertification• SVA GRIHA• GRIHA Rating• GRIHA for Large Developments• GRIHA PRAKRITI• GRIHA for EB
Schemes/Standards Available(Building Types)				
Ratings	Pass/Good/Very Good/Excellent/ Outstanding			one star to five stars
Weightings	Connected to each			

Information gathering Third party evaluation Certification Labeling Update process Governance Total Buildings Registered* Total Buildings rated* Square Ft Registered* Square Ft Rated* Professionals Trained* Total Footprints*	issue Category/ Consensus in view of open/logical consultation Design /Management team or Assessor BRE BRE Global Limited Annual UK Accreditation Service 2250911 549,749 - - - -	Homes• Neighborhood Development Certified/Silver/ Gold/Platinum All credits similarly weighted/albeit no of credits for every classification is their true weighting Design / Management team or Accredited Professional N/A US GBC(United States Green Building Council) As required US GBC(United States Green Building Council) 80,100 33500 7 billion sq ft 2 billion sq ft 201300 9 billion sq ft	Certified/Silver/ Gold/Platinum All credits similarly weighted/albeit no of credits for every classification is their true weighting Design / Management team or Accredited Professional N/A IGBC(Indian Green Building Council) till June, 2014 GBCI (Green Building Council of India) after June, 2014 As required IGBC(Indian Green Building Council) 3708 829 - - 1886 IGBC Accredited Professionals 3.82 billion sq ft	34 criteria having diverse no of points alloted GRIHA Council and Evaluation Committee Online Evaluation by Third Party Evaluators GRIHA(Initially developed by TERI and later modified by MNRE Technical Advisory Committee (TAC) National Advisory Council constituted by MNRE 750 - - - - 29 millions sqm

* This data has been obtained from their respective websites as on 13/10/2016

Careful study of the table 1 reveals that India has a large population density but its indigenous GBRS are way behind the US-LEED and BREEAM in their green footprints. The GRIHA National Rating System should give incentive for any qualifying project, open or private, being an administration upheld framework which accompanies motivating forces for the project proponement, the architect and the plan group. This would request that MNRE ought to track advancements and ought to have data about all ventures looking for GRIHA rating. Yet, MNRE keeps up data just for government ventures and does not distribute it on the website. The green certifications of the evaluated structures are the most misty part in India. No data is accessible on the genuine 'greenness' as far as particular outline estimates taken to accomplish energy, water proficiency, waste generation and reusing, and so forth. The credit points granted to the structures for different criteria are not available in public domain.

Both IGBC and GRIHA website claim that a rated building saves 30-50% energy, 20-30% water savings and the incremental cost for green building could be 2-

3 per cent more for which the payback period may be 5 years. But, no substantial information about the buildings rated has been disclosed. USGBC has rated a huge number of buildings and still keeps up pertinent documentation and fundamental subtle elements for open review about the appraised ventures dissimilar to its Indian counterpart IGBC and GRIHA. So Indian GBRS ought to work in a more straightforward way. More prominent responsibility and straightforwardness among the building segment partners is required particularly when public cash and extra built up area as FAR is included. Since India does not have a required composite lawful structure for post construction execution checking of structures, a building can't be assigned green just by intent for green certification. The information on real asset reserve funds must be kept up for compelling checking and record keeping amid the operational stage. But there is no post project monitoring for resource savings and impact reduction.

The table 2 shows the category mapping of the GBRS in the study. This mapping will give a fair idea of the different categories covered in each GBRS besides the mandatory accepted energy and environmental principles.

Table 2: Category Mapping of LEED-India and GRIHA to BREEAM

Category	BREEAM	LEED-India(Indian arm of US-LEED)	GRIHA
Management	Project brief and design Life cycle cost and service lifePlanning Responsible constructionpractices		Criteria 16: Reduce volume, weight and time of construction by adopting efficient technology (e.g. precast systems, ready mix concrete, etc.)(4) a.
Health and wellbeing	Commissioning and handover Aftercare Visual comfort Indoor air quality Safe containment in laboratories Acoustic performance Safety and security	Daylight and views(2) a. Minimum IAQ Performance(R)b. Environmental Tobacco Smoke (ETS) Control(R)c. Outdoor Air Delivery Monitoring(1)d. Increased Ventilation(1)e.	Criteria 26:Use of low VOC paints/ adhesives/sealants(4)b. Criteria 27:Minimize Ozone depleting substances(3)mandatoryc. Criteria 30:Tobacco and smoke control(1)
Energy	Reduction of energy use andcarbon emissions Energy monitoring External lighting	Construction IAQ Management Plan(2)f. Low Emi\miting Material(4) Indoor Chemical and pollutant Source control(1)	a. Criteria 13:Optimise building design to reduce conventional energy demand(6)b. Criteria 14:Optimise energy performance of building within specified comfort(12)c.
Transport	Energy efficient cold storage Energy efficient transportationSystems Energy efficient laboratorysystems		Criteria 18:Renewable energy utilization(5)partly mandatoryd. Criteria 19:Renewable energy based hot water system(3)
Water	Energy efficient equipment Drying space	Controllability of System(2) Thermal Control(2) Total: 15 a.	Criteria 32:Energy audit and validation(Mandatory)
Materials	Public transport accessibility Proximity to amenities	Renewable Energy(1-3)b. Ozone Depletion(1)c.	Criteria 6:Enhance outdoor lighting system efficiency and use RE system

	Cyclist facilities	Green Power(1)d.	for meeting outdoor lighting requirement(3)
	Maximum car parking capacity	CFC Reduction in HVAC & R Equipment(R)	
	Travel plan	a.	Criteria 7: Plan utilities efficiently and optimize on site circulation efficiency(3)
	Water consumption	Fundamental Building Systems Commisioning(R)b.	
Waste	Water monitoring		
	Water leak detection		
	Water efficient equipment	Additional Commisioning(1)c.	
		Minimum Energy Performance(R)d.	
	Life cycle impacts		
Land Use and Ecology	Hard landscaping and boundary protection	Optimized Energy Performance(1-10)e.	
	Responsible sourcing of materials	Measurement and Verification(1)	•
	Insulation	Total:17	Criteria 10: Reduce landscape water requirement(3)
	Designing for durability and resilience		•
Pollution	Material efficiency		Criteria 28:Ensure water quality(2)mandatory•
	Construction waste management		Criteria 11:Reduce building water use(2)•
Innovation	Recycled aggregates	Alternative Transportation(1-3)	Criteria 12: Efficient water use during construction
	Operational waste		
	Speculative floor and ceilingFinishes		
	Adaptation to climate change		a.
	Functional adaptability	Water Efficient landscaping(1-2)	Criteria 20:Waste water treatment(2)b.
	Site selection		Criteria 21:Water recycle and reuse(including rainwater)(5)
	Ecological value of site and protection ofecological features	Water Use Reduction(1-2)	a.
	Minimising impact on existing site ecology	Water efficiency in A/C Systems(1)	Criteria 15:Utilization of Fly ash in building structure(6)b.
	Enhancing site ecology	Innovative Waste water Technologies(1)	Criteria 17:Use low-energy material in interiors(4)
	Long term impact on biodiversity		Criteria 5:Reduce hard paving on site
	Impact of refrigerants		
	NOx emissions	a.	
	Surface water run-off	Local/regional Materials(2)b.	
	Reduction of night time lightpollution	Rapidly Renewable material(1)	Criteria 22:Reduction in waste during construction(2)
	Reduction of noise pollution	Certified Wood(1)	
	Innovation		a.
		Resource reuse(2)	Criteria 23:Efficient waste segregation(2)b.
		Total: 13	
		Construction waste management(3)	Criteria 24:Storage and disposal of waste(2)c.

		a. Recycled Content(2)b. Storage and collection of recyclables(R) Site Selection(1) Storm Water Design Light Pollution reduction(1) Innovation in Design	Criteria 25:Resource recovery from waste(2) Criteria 1:Site Selection(1) Partly mandatory Criteria 2:Preserve and protect landscape during construction/ compensatory depository forestation(5) Partly mandatory a. Criteria 3:Soil conservation(post construction(4)b. Criteria 4:Design to include existing site features(2)mandatory Criteria 5:Reduce hard paving on site(2)partly mandatory Criteria 29:Acceptable outdoor and indoor noise levels(2) Criteria 34:Innovation(4)Beyond 100

Note: The figures in the brackets denote the number of credits given for a criterion in the particular GBRS.

5. Parameters for sustainable structure

Though structural analysis and design of buildings is generally not included in the GBRS criteria, structural engineers can still contribute towards GBRS scores. The strategy of designing with durable materials, concrete with fly ash or high thermal mass matches the low operational and embodied energy concepts. Also, secure and save water guidelines can be met by utilizing least water in construction. Some different procedures can be, utilization of proficient and adaptable structural framework, outline for dismantling, dematerialization and utilization of sustainable materials. They can likewise contribute towards credits for integrated design process and advancement. Be that as it may, SSD includes significantly more than EE and material productivity. Keeping in mind the end goal of SSD in the GBRS under examination and in addition to recommend, all the credits and their relative weighting allocated to structural design are as in table 3.

Table 3: Percentage of sustainable structure design credits in the GBRSs

BREEAM(19%)	US-LEED(13%)	LEED-INDIA(15%)	GRIHA(12%)
• Man 2 Lifecycle cost and service life planning; • Mat 01 life cycle impacts; Mat 03 responsible sourcing of materials; Mat 05 design for durability and•	• IP: Integrative process. • M&R: building lifecycle impact reduction; • building• product disclosure and optimization — environmental product	• SA 1 integrated design approach; • BMR 1 sustainable building materials;• BMR 4 use of certified green building materials, products and equipment;	• 15:Utilization of Fly ash in building structure(6)• 22:Reduction in waste during construction(2)• Criteria 16: Reduce volume, weight and time of construction by adopting

resilience; • Mat 06 material efficiency; • Wst 01 construction waste management; • Wst 02 recycled aggregates; • Wst 05 adaptation to climate change; • Wst 06 functional adaptability	declaration;• building product disclosure and optimization—sourcing of raw materials;• building product disclosure and optimization–material ingredients;• construction and demolition waste management. • I: design for flexibility	• ID 2 optimization in structural design	efficient technology (e.g. precast systems, ready mix concrete, etc.)(4)• 3 4 Innovation

As can be seen, SSD is not being clearly accounted for in the credits allocation. Since the very essence of Green Building lies in integrated design involving all the stakeholders from the early stages of planning of the building, GBRS cannot limit the SSD to just material specifications (Sustainability Guidelines for the Structural Engineer, 2010). The null hypothesis that hazardous events can happen cannot be ruled out. Hazards, disasters and multidimensional threats are unpredictable events faced by communities resulting in major social and economic losses. Development with a renewed emphasis on sustainability and disaster resilience will help mitigating the financial, environmental, and community impacts. Life cycle impacts of building structures can be very large under extraordinary events. The structure's resilience to threats, hazards and disasters has to be considered in its analysis and design and is of much more significance than just specifying lower embodied energy materials. India's XI Five Year Plan's (FYP) center around disaster mitigation, instead of basically disaster response, requires reconciliation of disaster relief into the development procedure. India is one of the 168 nations that have ratified Hyogo Framework for Action (HFA). DRR will be a national and a neighborhood need which needs to be integrated with climate change adaption as credits in the criterion of GBRS. The SSD credits to be included in the GBRS for actual sustainable assessment have been identified in Table 4.

Table 4: Suggested Sustainable structure design credits

SSD Credit	Description
Integrated Design	Integrated decision making has to be done from the initial stages of the project
Life cycle cost and assessment	Life cycle cost analysis and impact assessment to be done to appraise design options
Renewable and recycled Materials	To meet a min % of renewable or recycled content
Responsible and local sourcing of materials	Legally harvested and less than 500 km sourcing
Material Efficiency	Design for material reduction, high strength materials for major structural elements, building reuse and design for disassembly
Construction waste management	To reduce C & D waste and recycle in-situ
Design for Durability	Design for durability to protect vulnerable parts during floods, cyclones
Design for resilience	Adaptation to climate change through risk assessment in order to mitigate against the expected increase in extreme weather conditions
Reliability	To ensure HVAC system and information technology equipment maintain their functionality in case of a hazard
Earthquake resistant design	To evaluate building's seismic capacity and higher scores for building exceeding codal requirements

Structural designs can be compared by specifying these reliable and comprehensive indicators for sustainability. The probabilistic approach used for setting structural performances during hazardous events can be included in sustainable performance. While catering to the environmental needs entails multidisciplinary approach, the humungous task of implementing structural performance needs fall to structural engineering.

6. Discussion

All GBRS are based on almost all environmental issues such as scarcity of materials, consumption of energy and water, pollution, indoor air quality and building site features. The different GBRS lay importance to environmental issues much more than economic and social issues. The economics of the building still gets counted for if efficiency optimization is considered with respect to energy, water or material used in construction. But the social issues such as "Influence on job market, labor availability, community disturbance, traffic congestion etc." have not been given due credits. Social issues like health and safety of workers during construction, air quality during construction have been given credits in GRIHA. Consumption of energy with resulting carbon emissions has been given maximum weightage in all the rating schemes. Energy can be counted under two heads- Embodied energy and Operational energy. All the GBRS give considerable importance to both by allocating credits under material efficiency and HVAC efficiency. Minimizing Material Production Energy entails reduce, reuse and recycle concepts towards materials used. Also, minimizing Embodied Energy by using structural systems with high thermal mass corresponds to sustainable structure design. On a broader perspective, all GBRS with their activities and processes lead to community benefits by energy security, lessening GHG emissions and strain on resources.

A one-size-fits-all GBRS would be hard to accomplish on a worldwide premise and also on nation premise. For instance, water scarcity can be a noteworthy issue in certain land area yet not in others. Sustainable power source choices like wind energy and sun based energy are likewise district particular. Distinctive issues should be positioned diversely to coordinate territorial condition and directions. BREEAM has possessed the capacity to adjust to neighborhood settings with BREEAM Bespoke where the assessor can work with BRE to create appraisal criteria custom fitted to a building and its location.

A key point that makes LEED more exportable is the presentation of regional extra credits. Six regional need credits in view of significance are given by US-GBC's regional boards in that locale. Nation particular renditions of LEED are being produced by singular national green building councils, Canada being the first, trailed by India. The Dutch Green Building Council has likewise embraced BREEAM as its assessment tool.

GRIHA recommends criteria 8 and 9 for least levels of sanitation/wellbeing offices for development laborers and to decrease air pollution amidst construction phase, each having 2 credits and made mandatory. These parameters are not explicitly defined in BREEAM and LEED, though they may have been covered in responsible construction practices. In India, these construction practices though may have been laid out but seldom practiced. All the GBRS except BREEAM do not specify criteria for durability and resilience of the structure. BREEAM considers this criterion only for the durability and resilience of the materials used in the exposed or internal elements of the structure. LEED and GRIHA consider SSD only in terms of Material and resource efficiency but structural analysis and design parameters have not been given any consideration. The role of structural engineers in achieving sustainable goals needs to be promoted, covering the range of economic, social and environmental issues over a lifecycle perspective under usual and hazardous events.

The way ahead for Indian GBRS would be to make the ratings transparent and provide information on costing and measures adopted for greenness. The Government will have to make a mandatory post construction performance monitoring framework to incentivize any fiscal or FAR benefits. Also, there is a need to improve technical readiness for achieving the predicted and modeled results. Public awareness campaigns should be initiated based on the validated performance information.

7. Conclusion

Organizations find 'reputation advantage' in exhibiting their green building credentials to the society in pursuance of sustainability. A holistic solution to include project planning, designing, constructing, operating and demolishing has to be adopted for sustainable development. This paper gives a comprehensive outline of development of Green building rating systems. Among the four GBRS

examined, US-LEED may be extending its arms to other countries in their respective contexts but BREEAM covers a wider perspective of sustainability issues. LEED-India and GRIHA have smaller green footprints and lack many categories as mapped to BREEAM. Studies focused on Government regulations, initiatives and incentives for executing green building practices in India need to be conducted. Sustainable Structure design strategies will have to be included in the criterion of GBRS since buildings are quite prone to hazardous events which have long term economic and social impacts. Further research should concern quantifying SSD practices into measuring impacts and develop explicit design alternatives. The Governments need to establish mandatory regulatory framework for efficiency of resource use and performance monitoring. It may be inferred that recognizing distinct aims, barriers, appropriate line of action/implementation and applying mandatory certification systems to control the occupant activities will definitely ensure sustainable development in construction.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

BRE, B. R. 1990. Building Research Establishment Environmental Assessment Method.

Al-Ghamdi, S. G., & Bilec, M. M. 2016, 07. Green building rating systems and whole-building life cycle assessment: Comparative study of the existing assessment tools. *Journal of Architectural Engineering* , 04016015.

Bhat, K. M. 2005. Forest education and research in India: Country report. *Forest Science and Technology, 1* (2), 185-192.

Bhatt, R., & Macwan, J. E. 2016. Fuzzy logic and analytic hierarchy Process–Based conceptual model for sustainable commercial building assessment for India. *Journal of Architectural Engineering , 22* (1), 04015009.

Bhatt, R., & Macwan, J. E. 2012. Global weights of parameters for sustainable buildings from consultants' perspectives in Indian context. *Journal of Architectural Engineering , 18* (3), 233-241.

Brundtland, G. H. 1987. *Our common future: Brundtland-report.* Oxford, U.K.: Oxford University Press.

Calgüner, T. 1999. Environmental impact assessment and the urban planning crisis in turkey. *Impact Assessment and Project Appraisal , 17* (2), 165-168.

Cole, R. J., & Kernan, P. C. 1996. Life-cycle energy use in office buildings. *Building and Environment , 31* (4), 307-317.

Elnokaly, A. 2014. A Cross Case Investigation of Sustainability Assessment tools of the LEED, BREEAM and GRIHA. In M. Vyas (Ed.). (p. 23). International Association of people-environment studies: IAPS.

Haapio, A., & Viitaniemi, P. 2008. A critical review of building environmental assessment tools. *Environmental Impact Assessment Review , 28* (7), 469-482.

Hamedani, A. Z., & Huber, F. 2012. A comparative study of DGNB, LEED and BREEAM certificate systems in urban sustainability. *WIT Transactions on Ecology and The Environment , 155*.

Horekens, J. 2007. Disaster Reduction and the Hyogo Framework for Action. *Refugee Survey Quarterly , 26* (4), 250-254.

IGBC. 2015. IGBC green new buildings rating system-Version 3.0.

Jibiki, Y. 2016. Preliminary Analysis on Science for Global Safety with Reference to the Sendai Framework for Disaster Risk Reduction. *Journal of Disaster Research , 11* (3), 421-424.

KAWAZU, Y., SHIMADA, N., & YOKOO, N. 2005. COMPARISON OF THE ASSESSMENT RESULTS OF BREEAM, LEED, GBTOOL AND CASBEE. (pp. 4-14). Tok: The 2005 World Sustainable Building Conference,.

Kibert, C. J. 2007. The next generation of sustainable construction. *Building Research & Information , 35* (6), 595-601.

Kosheleva, E., & Elliott, J. 2006. Green building in the Russian context: An investigation into the establishment of a LEEDbased green building rating system in the Russian federation. *Journal of Green Building , 1* (3), 105-123.

LEED textbar U.S. Green building council. 2016. ltd, I. 2010. *BREEAM versus LEED.* Inbuilt Ltd.

Maydl, P. 2004. Sustainable engineering: State-of-the-art and prospects. *Structural Engineering International, 14* (3), 176-180.

McManus, P. 2014. Defining sustainable development for our common future: A history of the world commission on environment and development (Brundtland commission). *Australian Geographer , 45* (4), 559-561.

Nguyen, T. H., Toroghi, S. H., & Jacobs, F. 2015, 04. Automated green building rating system for building designs. *Journal of Architectural Engineering* , A4015001.

NOTES FOR CONTRIBUTORS. 2011. *Forests, Trees and Livelihoods , 20* (2-3), 213-213 of New, M., renewable Energy, G., & Institute, T. E. (2016). The little book of GRIHA rating.

Pappu, A., Saxena, M., & Asolekar, S. R. 2007. Solid wastes generation in India and their recycling potential in building materials. *Building and Environment , 42* (6), 2311-2320.

Pongiglione, M., & Calderini, C. 2016, 07. Sustainable structural design: Comprehensive literature review. *Journal of Structural Engineering* , 04016139.

Potbhare, V., Syal, M., & Korkmaz, S. 2009. Adoption of green building guidelines in developing countries based on U.S. And India experiences. *Journal of Green Building , 4* (2), 158-174.

Rezaallah, A., Bolognesi, C., & Khoraskani, R. A. 2012. LEED and BREEAM; Comparison between policies, assessment criteria and calculation methods. At: BSA 2012 – Proceedings of the 1st International Conference on Building Sustainability Assessment.

Said, H., Kandil, A., Nookala, S. B., Cai, H., El-Gafy, M., Senouci, A., et al. 2014. Modeling of the sustainability goal and objective setting process in the Predesign phase of green institutional building projects. *Journal of Architectural Engineering , 20* (2), 04013007.

Sarkisian, M., & Shook, D. 2014. Embodied carbon in structures and cities. *IABSE Symposium Report , 102* (3), 3166-3173.

Seager, A. 2007, 02. Construction sector rises to challenge of building eco-friendly homes of the future. *The Guardian* .

Selman, P. 1996. Book reviews: Carew-Reid, J., Prescott-Allen, R., bass, S. And Dalal-Clayton, B. 1994: Strategies for national sustainable development: A handbook for their implementation. London: Earthscan. Xviii + 204 pp. F14.95 paper. ISBN: 1853 83 193X. *Progress in Human Geography , 20* (2), 266-267.

Sjostrom, C., & Bakens, W. 1999. CIB agenda 21 for sustainable construction: Why, how and what. *Building Research & Information , 27* (6), 347-353.

Sustainability Guidelines for the Structural Engineer. 2010. American Society of Civil Engineers (ASCE).

Sustainability: An international perspective. 1998. *Building Research & Information , 26* (2), 74-75.

TERI. 2007. Green Rating for Integrated Habitat Assessment.

US Forest Service. 2011. *Choice Reviews Online , 49* (02), 49-0851-49-0851.

USGBC. 2016. LEED credit library textbar U.S. Green building council.

Varghese, P. 2016. Exploring other concepts of smart-cities within the Urbanising Indian context. *Procedia Technology , 24*, 1858-1867.

wbcsd. (n.d.). Retrieved 10 10, 2016, from world building council of sustainable development web site: www.wbcsd.org

WGBC. (n.d.). *World Green Building Council*. Retrieved December 24 , 2017, from World Green Building Council 2016-17: http://www.worldgbc.org/benefits-green-buildings

Wu, P., & Low, S. P. 2010. Project management and green buildings: Lessons from the rating systems. *Journal of Professional Issues in Engineering Education and Practice , 136* (2), 64-70.