REVIEW OF REGENERATIVE DESIGN THEORIES FOR SCHOOL BUILDINGS IN THE TROPICS OF INDIA

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The Trajectory of Environmentally responsive design by Bill Reed [1] maps paradigm shift from degenerating to regenerating systems. The trajectory depicts sustainable system as neutral. Regenerative design integrates ecological system in the built environment and is based on the premise that everything built has the potential for the integration of the natural world as an "equal partner" in the architecture. The design profession is bestowed with legendary individuals who have attempted to translate ecological processes into something meaningful and useful for design theories.

This paper will focus on recent trends and representative theories that followed the influential social, economic, and ecological movements of the 1960s and 1970s. The works of Malcolm Wells, Nancy Jack Todd and John Todd, William McDonough, John Tillman Lyle, Sim Van der Ryn and Stuart Cowan, Bill Reed, and Raymond J. Cole continue to influence the evolution of regenerative design thought and practice.

The paper reviews regenerative design theories and explore ways in which ecological processes have been interpreted through design at the end of the first decade of twenty first century. Each theory will be summarized and considered for regenerative design of schools for thermal comfort in the tropics of India. This study is significant as India has about one million schools and out of which 80% are government schools. The paper argues that regenerative design for school building would create environmentally responsive learning environment.

Keywords: Regenerative Design, Schools, Sustainable, tropics.

Introduction

The definition of school as per oxford dictionary is "An institution for educating people". In the ancient times in India, the schools (called as *Gurukuls*) were the centres of learning in natural setting; where the overall development of the child in terms of physical, mental and spiritual took place living with the nature.

As the climate in India is predominately tropical, the *gurukuls* used to be open schools where all pupils (*shishyas)* lived together as equals irrespective of their social standing, learn from the teacher (*guru)* and carry out daily chores. These traditional schools were located in a natural environment away from the hustle and bustle of the town. The materials used in these traditional schools were locally available materials. These schools were the best example of environmentally responsive architecture where the *shishyas* learnt the principles of sustainability right from their early childhood.

A contemporary example of *gurukul* is, Visva Bharti campus, Shantiniketan, West Bengal, India set up by the Nobel Laureate Guru Ravindra Nath Tagore, Fig. 1 (a). It is India's most renowned places of higher learning in a natural context.

The contemporary Indian school buildings are mostly concrete structures, Fig. 1 (b) and devoid of environmental integration, standing as disintegrated elements on the site. Hence, with technological advancement, schools instead of the centre of learning the lessons of living a natural life are the centre of

Fig 1 (a): Traditional model of open air Classrooms, Shantiniketan, WB, India
Source: http://muktodhara.org/wp-content/uploads/2013/06/201.jpg1.jpg

Fig 1 (b): Contemporary model of enclosed classrooms, Jawahar Navodaya Vidyalay, India
Source: http://jnvhowrah.bih.nic.in/

learning to live an artificial life. These lessons, of course, cannot be taught through books only but are to be experienced by sustainable built environment and by direct interaction with the eco systems.

Architecture and ecology

As architecture is a human activity, hence in order to cater to growing energy demand of the buildings, fossil fuels are burnt at an alarming rate, thereby emitting green house gases in the environment and as a result of that, bringing about global climate change. In addition to energy, pollution and climate change issues, construction activity contributes to soil erosion, increased landfill wastes as well as environmental pollution from manufacturers of building materials. Non-sustainably harvested wood used for construction depletes our forests, disrupts wildlife habitat, contributes to stream siltation and reduces oxygen levels needed for life on earth [2]. Due to this, the ecological balance to sustain life on earth is getting disturbed and the survival of our own self and our future generations is in peril.

Currently linear model of development is in use; which extracts resources from the earth, consumes them and after completion of life cycle of the product, dumps the waste in the nature. Hence, the waste thus generated is exceeding the carrying capacity of the earth to absorb it. Consequently, it has become imperative to explore the natural ecological processes to maintain the ecological integrity of our biosphere and employing energy efficient strategies to reduce the energy consumption and alternative renewable sources to generate energy in the buildings.

Regenerative architecture:
road to partnership with nature

Sustainability was defined at the 1987 UN conference as development that "meets present needs without compromising the ability of future generation to meet their needs" [3]. Currently, building design approach is to make them 'less bad' than other buildings with a tag of being sustainable but sustainability has come a long way since its definition was first coined in 1970s. The current sustainability approach tends to make the buildings more and more energy efficient, thereby just lessening the burden on the earth's non renewable resources but the problem is, it is not sufficient to sustain our life on earth.

In view of the environmental degradation and limited natural resources, the designers' focus is now shifting from making the buildings 'less bad' to engaging the natural environment as generator. Bill Reed, in his pioneering work offers a definition of Regenerative architecture as:

> "A conservation or high performance approach focused on reducing our impact and a living system understanding focused on as how we engage nature as a co-equal partner" [1].

Regenerative approach goes beyond net zero energy approach to make the buildings net positive energy buildings through participation in the health building process of our mother planet. So whatever damage humans have done so far to the planet, not only it is restored back to its degraded environment but also starts healing and treating the natural environment as equal shareholder in the architecture. It is a closed loop development in which the waste being generated after the completion of the life cycle of a product, acts as a raw material for other organisms in the nature.

During late 1970s, John T Lyle challenged his graduate students to design a community which lives within limited resources without causing any harm to the environment. The students worked hard to develop design for an institutional building at Cal Pol University at Pomona, US. Since then, many biologists, architects, ecologists, environmentalists have come up with theoretical approaches on Regenerative architecture and have attempted to translate ecological processes into something meaningful and useful for design theories. To name a few, the works of Malcolm Wells, Nancy Jack Todd and John Todd, William McDonough, John Tillman Lyle, Sim Van der Ryn and Stuart Cowan, Bill Reed, and Raymond J. Cole continue to influence the evolution of regenerative design thought and practice.

This paper presents and analyses the theoretical approaches on Regenerative design developed so far by theorists and ecologists all over the world along with their applications in the built as well as natural environment and also review their relevance and applications in regenerative design of the schools in the tropical climate of India.

A wilderness based checklist
by Malcolm Wells

Malcolm Wells advocated environmentally responsible design and promoted the idea of modern earth-sheltered architecture.

> "In 1964, after 10 years spent spreading corporate asphalt on America in the name of architecture, I woke up one day to the fact that the earth's surface was made for living plants, not industrial plants. I've been an underground architect ever since" [4].

He designed underground structure for his own living in which he covered the roof with layers of earth with grass on top. His designs mainly speak of his love for nature and preserving nature while designing his buildings. Wells speaks about underground architecture:

> "...A building should consume its own waste, maintain itself, match nature's pace, provide wildlife habitat, moderate climate and weather and be beautiful. That's a series of pass/fail evaluation criteria..."

He developed a regeneration based checklist for design and construction. The checklist sets the wilderness as the model for design. His checklist has been organized into site and building issues and rates different environmental parameters like air quality,

water quality, protection of wildlife habitat, waste management, rain water conservation, harnessing natural light in the building using passive heating and cooling strategies etc. on a –100 to +100 scale. The scores show transition from degeneration to regeneration.

The wilderness-based checklist and related daylighting [5] and thermal comfort concepts are summarized in Table 1.

Living machines by Nancy Jack Todd and John Todd

Amongst all the theorists and ecologists, work by Nancy Jack Todd and John Todd is pioneering in understanding the living relationship between our biotic and abiotic environment. John Todd developed self sustaining living machines based on ecosystem technologies which treat sewage and purify water with plants, animals and microorganisms to maintain ecological balance in the nature.

"The final thing about living machines is that they are designed to do work. And by work I mean to grow food, to generate fuels, keep cool and regulate buildings, treat waste, and integrate all of the above" [6].

Dr. Todd founded John Todd Ecological Design centre which has installed Eco Machines based on his ecological philosophy in many countries around the world. The Design centre has also installed Eco machines in Darrow School, New Lebanon, New York which treat waste water from school dormitories and other buildings before making it flow back to Hudson River watershed area. In addition to treating wastewater, the Eco-Machine provides a setting for educational activities. Students regularly monitor levels of bacteria, phosphorous, nitrogen, and other biological and chemical levels. They observe and maintain plant life which grows in the aquatic treatment tanks throughout the facility. By participating in this ecological solution, concepts of sustainability are more effectively conveyed. The nine precepts and related daylighting [5] and thermal comfort interpretations are summarized in Table 2.

Table 1

Malcolm Wells-A Wilderness Based Checklist

Malcolm Wells – Wilderness Based Checklist [4]	Related Daylighting Concepts [5]	Related Thermal Comfort Concepts for Schools
1. Creates pure air	1. Combine daylighting and natural ventilation	1. Combine thermal comfort and natural ventilation
2. Creates pure water	2. Integrate daylighting and biological waste treatment systems	2. Integrate solar energy and biological waste treatment systems
3. Stores rainwater	3. N/A	3. N/A
4. Produces its own food	4. Include conservatories, greenhouses, and sunspaces	4. Include conservatories, greenhouses, and sunspaces
5. Creates rich soil	5. N/A	5. N/A
6. Uses solar energy	6. Couple daylighting with passive solar design	6. Provide thermal comfort with passive solar design
7. Stores solar energy	7. Couple daylighting with passive solar design	7. Provide thermal comfort with passive solar design
8. Creates silence	8. N/A	8. N/A
9. Consumes its own wastes	9. Integrate daylighting with biological waste treatment systems	9. Integrate thermal comfort with biological waste treatment systems
10. Maintains itself	10. Use daylighting to minimize the need for mechanical lighting, heating, and cooling	10. Provide solar passive design to minimize the need for mechanical lighting, heating, and cooling
11. Matches nature's pace	11. Use daylighting to enhance awareness of natural cycles, seasons, and time of day	11. Use thermal comfort to enhance awareness of natural cycles, seasons, and time of day
12. Provides wildlife habitat	12. N/A	12. N/A
13. Provides human habitat	13. Use daylighting to create meaningful and healthy spaces for people	13. Use thermal comfort to create meaningful and healthy spaces for people
14. Moderates climate and weather	14. Use daylightlng strategies that are appropriate for the climate, site, and region	14. Use passive solar design strategies that are appropriate for the climate, site, and region to provide thermal comfort
15.... and is beautiful	15. Explore the aesthetic and experiential opportunities of daylighting	15. N/A

Hannover principles by William McDonough

William McDonough, an architect and an environmentalist published The Hannover Principles, in 1992 [7]; these principles served as design guidelines for the World's Fair 2000 in Hannover, Germany. McDonough explains: "The Hannover Principles should be seen as a living document committed to transformation and growth in the understanding of our interdependence with nature, in order that they may adapt as our knowledge of the world evolves." A variety of factors, including content and timing, have made the Hannover Principles among the most widely distributed ecological design concepts. The Hannover Principles can be viewed as a call to action. Drawing on the body of ecological design thinking, McDonough frames the issues from a moral and ethical perspective.

McDonough says [8]:

> "By using the terms; green, high performance buildings, sustainable architecture, we are only trying to be 'less bad' instead of being good. This approach is quite dangerous for the health of our planet. Also the current design problem is our faulty industrial system which generates waste as an outcome of consumption and economic activity."

McDonough developed Cradle to Cradle (C2C) design philosophy. The model categorizes all the material into 'technical' and 'biological'. Technical materials are non-harmful, non-toxic and synthetic materials which can be safely recycled without losing their integrity and quality while the Biological materials are easily decomposed into food for other living organism. Table 3 summarizes the Hannover Principles and related daylighting [5] and thermal comfort concepts.

Strategies for regenerative design by John Tillman Lyle

John Tillman Lyle, an ecologist, questioned a linear throughput model of current development. As per this model, in the present technologically advanced world, the waste of the industrial activity after its entire life cycle goes towards the sinks (air, water, land); which are

Table 2

John Todd and Nancy Jack Todd –Nine Precepts for Ecology as the Basis for Design

Precepts for Ecology as the Basisfor Design [6]	Related Daylighting Concepts [5]	Related Thermal Comfort Concepts for Schools
1. The living world is a matrix for all design	1. Explore the daylighting lessons that can be learned from ecological processes	1. Explore the ecological processes to learn thermal comfort lessons.
2. Design should follow, not oppose, the laws of life	2. Respond to solar phenomena and diurnal and seasonal patterns	2. Integrate the laws of life into design to provide thermal comfort
3. Biological equity must determine design	3. Provide daylighting to all occupants; consider the political implications of light	3. Integrate thermal comfort design strategies with the natural systems to bring about biological equity
4. Design must reflect bioregionality	4. Respond to climate, weather, environmental forces, site, and place	4. Respond to climate, weather, environmental forces, site, and place
5. Projects should be based on renewable energy sources	5. Integrate daylighting, electric lighting, and passive systems	5. Combine renewable sources of energy with passive solar design strategies to provide thermal comfort
6. Design should be sustainable through the integration of living systems	6. Integrate daylighting with solar aquatic waste treatment systems and greenhouses	6. Integrate thermal comfort with solar aquatic waste treatment systems and greenhouses
7. Design should be coevolutionary with the natural world	7. Explore the relationship between daylighting technologies and natural systems; design daylighting to be flexible and adaptable	7. Explore the relationship between passive solar design strategies and natural systems
8. Building and design should help to heal the planet	8. Create healthy and healing places of light; minimize the consumption of natural resources and related environmental impacts	8. Integrate passive solar design strategies with use of natural materials which after completion of their life cycle decompose in the nature.
9. Design should follow a sacred ecology	9. Consider how daylighting can reveal the interconnection between humans and the natural world	9. Consider how thermal comfort parameters can reveal the interconnection between humans and the natural world

Table 3

William McDonough- The Hannover Principles

Hannover Principles	Related Daylighting Concepts [5]	Related Thermal Comfort Concepts for Schools
1. Insist on Rights of Humanity and Nature to Coexist in a Healthy, Supportive, Diverse and Sustainable Condition	1. Consider the physiological and psychological implications of light as well as broader issues of health and well-being	1. Harness solar and wind energy by providing renewable sources of energy and combine them with passive solar design to provide Sustainable design
2. Recognize Interdependence. Expand Design Considerations to recognize even Distant Effects	2. Use daylighting to reduce waste and resource consumption, promote health and well-being, and create beauty	2. Integrate high quality technical and organic materials which decompose in the nature with passive solar design
3. Respect relationships between spirit and matter	3. Use daylighting to improve quality of life; consider the spiritual implications of light	3. Combine passive solar design with earth's natural systems to improve quality of life and spiritual ascent of the self
4. Accept Responsibility for the consequences of Design Decisions Upon Human Well-Being, The Viability Of Natural Systems and their right to coexist	4. Use daylighting to enhance the relationship between inside and outside; respond to climate, weather, and place	4. Use natural thermal comfort strategies to enhance the relationship between inside and outside; respond to climate, weather, and place
5. Create safe objects of long-term value. Do not burden future generations due to the careless creation of products, processes, or standards	5. Develop low-maintenance daylighting and electric lighting designs; use durable and dependable lighting components	5. Integrate and use only organic and technical materials in the buildings with passive solar design
6. Eliminate the concept of waste; evaluate and optimize the full life cycle of products and processes	6. Develop energy-efficient design; use daylighting to reduce electric lighting; use daylighting to do more with less; design for adaptability and flexibility	6. Remove heavy and dangerous technical materials which do not decompose in the nature from current life cycle
7. Rely on natural energy flows	7. Integrate daylighting with passive solar strategies, solar aquatic waste treatment systems, and greenhouses	7. Integrate passive solar strategies with daylighting, solar aquatic waste treatment systems, and greenhouses
8. Understand the limitations of design. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled	8. Develop daylighting to respond to environmental forces, site, and solar phenomena; consider how ecological processes can transform daylighting	8. Integrate natural processes in the Sustainable design of the buildings
9. Seek constant improvement by the sharing of knowledge	9. Share daylighting design knowledge with others; educate clients and users	9. Share the knowledge of the Sustainable design with others for further improvement

already loaded far beyond their capacities. Lyle suggests replacing the present linear system of material flow with cyclical flows at sources, consumption centers and sinks [10]. Centre for Regenerative Studies, California State Polytechnic University, Pomona designed by Lyle is based on the concept of building a functioning human ecosystem. The 12 strategies for regenerative design and related daylighting [5] and thermal comfort implications are summarized in Table 4.

Ecological principles by Sim Van der Ryn

Sim Van der Ryn, an architect, academician and environmentalist suggested Regenerative design philosophy based on basic principles of ecological design which not only gave a positive direction to Regenerative design movement but also filled up the gap in between sustainable design theories and ecology [11]. He weaved ecological principles into the built environment by their application into architecture. He described the definition of sustainability as:

> "A concept which is multi faceted, encompassing economic, social, political, cultural, spiritual and ecological dimensions" [12].

His architectural design solutions vary with humans, place, climate and ecology. His regenerative design philosophy is based on five basic principles promote the healthy interaction between hu-

Table 4

John Tillman Lyle: Strategies for Regenerative Design

Strategies for Regenerative Design	Related Daylighting Concepts [5]	Related Thermal Comfort Concepts for Schools
1. Letting nature do the work	1. Integrate daylighting and passive systems to minimize dependency on fossil fuels	1. Integrate passive systems to minimize dependency on fossil fuels
2. Considering nature as both model and context	2. Consider how ecological processes inform daylighting design	2. Integrate earth's natural systems for heating or cooling the buildings.
3. Aggregating, not isolating	3. Integrate daylighting with heating, cooling, and mechanical systems	3. Integrate natural processes into thermal comfort design of the buildings
4. Seeking optimum levels for multiple functions, not the maximum or minimum for anyone	4. Use daylighting to achieve multiple goals (illumination. ventilation, thermal gains, electricity generation, etc)	4. Keep a balance between natural systems and human interventions
5. Matching technology to need	5. Use daylighting for illumination; select appropriate lighting technologies based on program, activities, and scale	5. Combine technology with passive solar systems to provide optimum thermal comfort levels
6. Using information to replace power. ... Given adequate information, we can achieve precise fits between system and function	6. Design daylighting to respond to program and function	6. Design thermal comfort to respond to program and function
7. Providing multiple pathways. In most cases, regenerative technologies are relatively small in scale and suited to specific applications under particular conditions ... (i.e.. combining photovoltaic and wind)	7. Create lighting diversity in the luminous environment; use bilateral and multilateral strategies; provide flexibility and adaptability	7. Combine renewable sources of energy with electrical back up to achieve optimum levels of thermal comfort
8. Seeking common solutions to disparate problems	8. Consider daylighting from multiple perspectives: environmental, architectural, and human factors	8. Conserve site contours, orient the building in the right direction to maximise daylighting, thermal comfort and natural ventilation
9. Managing storage as a key to 'sustainability	9. Link daylighting to passive solar strategies	9. Link thermal comfort to passive solar strategies
10. Shaping form to guide flow	10. Shape the form of the building massing, plan, and section to maximize daylighting	10. Orient the buildings in the right direction and providing suitable form to achieve maximum thermal comfort
11. Shaping form to manifest process	11. Use form, materials, and systems to express daylighting concepts	11. Use form, materials, and systems to express thermal comfort concepts
12. Prioritizing for sustainability	12. Make daylighting a priority	12. Make thermal comfort a priority

mans and the ecological environment and provide integration between the built and the natural environment. Sim applied these principles in the design of Ojai Foundation School, California and many other buildings. The ecological design of the school conforms to site contours and uses excavated site materials for rammed earth walls and appropriate passive technologies for cooling, heating and lighting. The five principles and related daylighting [5] and thermal comfort implications are summarized in Table 5.

Work by Raymond J Cole

Raymond J Cole, an environmentalist and an architect has a great concern for integration of Regenerative design principles as an essential approach for the designing of the buildings. Cole provides the key characteristics of green design and associated assessment methods as the basis for highlighting distinctions and relationships with sustainability and regenerative approaches.

The emphasis and language of green design is largely one of reducing resource use and adverse environmental impacts of buildings. Regenera-

Table 5

Sim Van der Ryn and Stuart Cowan- Second Generation Ecological Design

Second Generation Ecological Design	Related Daylighting Concepts [5]	Related Thermal Comfort Concepts for Schools
1. Solutions Grow From Place	1. Develop Daylighting Design in Response to Environmental Forces, Site and Place	1. Develop Thermally Comfortable Design in Response to Environmental Forces Site, And Place
2. Accounting Informs Design	2. Consider the Relationship Between Daylighting, Energy And Natural Resources; Address Systems Integration; Consider Life-Cycle and Environmental Costs	2. Consider the Relationship Between Thermal Comfort, Daylighting, Energy and Natural Resources; Address Systems Integration; Consider Life-Cycle and Environmental Costs
3. Design With Nature	3. Draw on the Lessons Of Natural Processes (Adaptation, Evolution, Self-Maintenance, Etc); Respond To Natural Forces; Consider The Relationship Between Daylighting And The Health Of The Environment And Occupants	3. Make The Design Harmonious By Integrating Solar Passive Design Strategies with the Natural Environment
4. Everyone is a Designer	4. Develop a Collaborative, Interdisciplinary Approach to Daylighting Design; involve Clients, Occupants, Maintenance Staff	4. Involve All the Stakeholders in the Design Process to evolve a Sustainable Design
5. Make Nature Visible	5. Use Daylighting To Reveal Natural Forces, Enhance A Sense Of Place, Connect With The Environment Illustrate Patterns Of Energy Consumption	5. Connect the Design with the Nature by Judicious Planning, Integrating Thermal Comfort Parameters and merging Inside with the Outside World

tion, in contrast, carries the positive message of considering the act of building as one that can give back more than it receives and thereby over time building social and natural capital [13].

Cole asserts that in between green and regenerative design approach, the later yields positive results and engages the natural world as equal stakeholder.

> While the green building assessment tools evaluate the individual performance of a building relative to a benchmark, either implicitly or explicitly, rather than in their absolute consequence on human and natural systems, the regenerative design approach on the other hand, promotes a co-evolutionary, partnered relationship between humans and natural systems rather than a managerial one and in doing so, builds social and natural capitals [14].

His work deals in reviewing the various Green, Sustainable and Regenerative building environmental assessment methods currently in use all over the world to evaluate the specific aspects of building performance such as annual energy use, illuminance distribution, day lighting etc. both during design development and for completed buildings.

Trajectory of environmentally responsive design by Bill Reed

Bill Reed formulated a Trajectory of environmentally responsive design articulating conventional; green, sustainable, restorative and regenerative designs against energy usage and environmental impact [1]. The trajectory maps degeneration to regeneration design approaches. Regeneration is a process of engagement with the purpose of healing living systems (humans and nature) and birthing a new spirit to consciously participate in expanding the healing process. Reed argues living system approach to design, understanding the interrelationships between water, soil, sun and shelter – the basic systems that support us and all species. The study proposes seven steps design process:

1. Setting the stage – understanding and aligning human aspirations of a project.
2. Learning about the place.
3. Frame/sketch/outline the story of place.
4. Marrying story of place with aspirations for future.
5. Identify indicators.
6. Integrative design/construction process.
7. Sustaining sustainability.

Regenerative approach is exemplified in Willow School, Bedminster, NJ designed by Reed [16]. The site is being designed as a living class room integrating the ecological principles. The ecological design features include a constructed wetland for wastewater treatment and using the treated water for irrigation and toilet water supply, use of porous paving for water permeability; green roof, bio swales and 60,000 plugs

Table 6

Comparison of Regenerative design theories/concepts by ecologists and theorists

Malcolm Wells: wilderness based checklist	Nancy Jack Todd and John Todd: Living machines	William McDonough: Cradle to cradle design philosophy	John Tillman Lyle: Regenerative design strategies	Sim Van der Ryn: Ecological Principles	R J Cole: Review of Building Environmental Assessment methods	Bill Reed: Trajectory of Environmentally Responsive design
1. Rates different environmental parameters on -100 to +100 scale. 2. Uses earth for 'living plants' and underground space for 'Industrial plants'. 3. Protects the eco system of the earth. 4. Uses earth's natural systems to cool/heat up the buildings.	1. Self sustaining. 2. Based on living relationship between our biotic and abiotic environment. 3. Based on ecosystem technologies. 4. Treat sewage and purify water with plants, animals and microorganisms. 5. Maintain ecological balance in the nature.	1. Believes in repaying the earth in return for what it has given us. 2. Suggests to protect and enrich eco systems and nature's biological metabolism. 3. Categorizes all the material into 'technical' and 'biological'. 4. Suggests the use of organic and technical nutrients. 5. Suggests removing dangerous technical materials from current life cycle.	1. Letting Nature Do the Work 2. Considering Nature as Both Model and Context 3. Aggregating, Not Isolating 4. Seeking Optimum Levels for Multiple Functions, Not the Maximum or Minimum Level for Any One 5. Matching Technology to Needs	1. Solutions Grow from Place. 2. Ecological Accounting. 3. Design with Nature. 4. Everyone is a Designer. 5. Making Nature Visible.	1. Comparison between Green and Regenerative design approach. 2. The Regenerative design approach promotes a partnered relationship between humans and natural systems. 3. Regenerative design approach yields positive results and engages the natural world as equal stakeholder.	1. Suggests moving from degeneration to regeneration. 2. Regenerative design is living system approach of design. 3. Exemplifies Regenerative Design approach in the design of Willow School, Bedminster, NJ.

of adapted species meadow planting to reduce storm water runoff and use of a deep wetland for storm water treatment. The school is a living example of creating a healthy, safe and sustainable environment for the school children where the students not only study the aspects of regenerative design but also become a part of that environment to learn and imbibe the essentials of ecological design.

Discussion and conclusions

The theories and related regenerative principles, precepts and strategies illustrate spectrum of translating ecological processes for design. Although the theories vary in format, content, and tone, they all have common strand of drawing on the lessons of nature for design, Table 6. Mary Guzowsky [5] reinterpreted these works to apply to daylighting design; this research expands these works to achieve thermal comfort in tropics of India. When comparing the propositions of the various authors, the concepts that are particularly relevant for thermal comfort are:

- Use nature as a model.
- Consider bioregions.
- Design for coevaluation and flexibility
- Use renewable energy sources and natural energy flows.
- Seek self-maintaining and regulating systems.
- Promote health and healing.

These concepts are equally relevant for campus planning, landscape design, interior design, building construction and other design consideration. These concepts of regenerative design are expansive and inclusive, will clearly lead us toward a more sustainable future.

This research argues that the principles of Regenerative design are relevant for design of schools buildings in tropical climate of India. In India, the government is the major provider of education. As per Hon. Supreme Court directive to introduce Environmental education as a first step towards sustainable development in schools, the Government of India established Jawahar Navodaya Vidyalaya Samiti in 1985 to set up unique educational institutions across the country for the holistic development of the rural students. Considering that there are over 1.3 million government schools in India and we need more schools to cater to over 140 million more children [22], the research will be relevant in applying Regenerative design principles on a large scale in government schools.

In India, Bureau of Energy Efficiency (BEE) [24] has published guide book for energy management for the schools. The Ministry of New and Renewable Energy, Government of India has laid down Green Rating for Integrated Habitat Assessment (GRIHA) [23] rating systems for existing day schools. These rating systems primarily aim for high performance design and would need to be enhanced towards Regenerative design engaging all the key stakeholders and processes of the place like humans, biotic systems, abiotic systems and above all the higher consciousness which connects all the systems together and energises them.

Since our ancient schools (*gurukuls*) were designed on regenerative principles only, hence the transition to regenerative approach based on various theories and principles being developed by ecologists and theorists will include all the stakeholders and invite the designers to shift their focus to our traditional knowledge and combine the same with the contemporary technical knowhow to provide environmentally responsible built environment for the schools in India.

The regenerative design approach takes into account development of regenerative design framework within which all the aspects of ecology, place, culture and the climate are woven.

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Received 21 September 2014

УДК 711.57(540) + 725.4.012(540)

Bulletin of the South Ural State University
Series "Construction Engineering and Architecture"
2014, vol. 14, no. 4, pp. 5–14

ОБЗОР ТЕОРИЙ РЕГЕНЕРАТИВНОГО ПРОЕКТИРОВАНИЯ ШКОЛЬНЫХ ЗДАНИЙ В ТРОПИКАХ ИНДИИ

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Траектория развития экологически чувствительного проектирования в соответствии с парадигмой Билла Рида изменяется от вырожденных до регенеративных систем. Траектория изображает устойчивую систему в качестве нейтральной. Восстановительное проектирование интегрирует экологическую систему в антропогенную среду и базируется на положении о том, что все построенное обладает потенциалом интеграции мира природы в архитектуру в качестве «равноправного участника». Профессия проектировщика связана с легендарными личностями, пытающимися перевести экологические процессы во что-то полезное и значимое для теорий проектирования.

Работа рассматривает современные тенденции и сопутствующие теории, которые следовали существенным социальным, экономическим и экологическим движениям 1960–70-х гг. Работы Малкольма Уэллса, Нэнси Джек Тодд и Джона Тодда, Уильяма Мак Донова, Джона Тильмана Лайла, Сим ван дер Рина и Стюарта Кауэна, Билла Рида и Реймонда Дж. Коля продолжают оказывать воздействие на развитие теории и практики регенеративного проектирования.

Работа проводит обзор теорий регенеративного проектирования, а также исследует методы, при помощи которых экологические процессы рассматриваются через проектирование в конце первого десятилетия XXI века. Каждая теория формулируется и рассматривается для регенеративного проектирования школ в зоне температурного комфорта в тропиках Индии. Данная работа представляет собой большой интерес, поскольку в Индии находится порядка 1 миллиона школ, из которых 80 % – государственные. В работе утверждается, что регенеративное проектирование школьных зданий создаст экологически чувствительную учебную среду.

Ключевые слова: регенеративное проектирование, школы, устойчивый, тропики.

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Поступила в редакцию 21 сентября 2014 г.