Central Public Works Department (CPWD)

In the service of the nation since 159 years

Under the Ministry of Urban Development, Government of India, CPWD provides single window services for all facets of government built environment in India and abroad.

With its huge resource of skilled and competent engineers, architects and horticulturists, CPWD's strength is its country-wide presence, with proven ability to undertake a whole range of complex constructions under difficult terrains. The department has the capacity to undertake construction varying from the smallest works in the remotest of places to mega projects in metro cities. These works include the construction and maintenance of government structures such as residential complexes, offices, schools, laboratories, hospitals, sport facilities, stadia, gymnasia, auditoria, storages, highways, flyovers, tunnels, bridges, jetties, airports, runways and border fencing. Intra-campus facilities such as water and electric supply, sewerage and treatment plants are also provided.

CPWD also performs other functions such as the custody of estates, valuation, rent assessment, technical advice to government, consultancy services, standardization and benchmarking, State Ceremonies (Republic Day, Samadhi, etc.) processing of DPRs for development of urban infrastructure under JNNURM and works of other Ministries for centrally funded works. CPWD also assists in organizing public and ceremonial functions, and upkeep of historical and important monuments and structures.

CPWD Guidelines for Sustainable Habitat

CPWD also publishes various documents to help the construction industry. This publication is a further step forward in the department's commitment towards sustainable habitat.

CPWD

CENTRAL PUBLIC WORKS DEPARTMENT

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सत्यमेव जयते

CPWD GUIDELINES FOR SUSTAINABLE HABITAT

CPWD

Central Public Works Department

March, 2014

www.cpwd.gov.in

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FOREWORD

Central Public Works Department under the Ministry of Urban Development, Govt. of India is entrusted with construction and maintenance of buildings for Central Govt. Ministries/ Departments, Public Sector Undertakings and Autonomous bodies. Over the last 159 years, CPWD has been in an endeavor to accomplish this task by using locally available materials and Energy Efficient Sustainable technologies. CPWD has been a pioneer in construction industry with regards to sustainable approach as being the first to prohibit use of wood in construction work and playing a lead role in use of fly ash. CPWD is also committed to buildings conforming to minimum 3 star rating in all its projects reinforcing its outlook to environment friendly construction.

To build a sustainable habitat, sustainable materials and technologies are to be dealt in a more comprehensive manner. Therefore, there is need for a document containing ready guidelines for sustainable technologies and to evaluate the use of materials based on sustainability index. The objective of CPWD guidelines on sustainable habitat is to help the Architect/Engineers while taking decision on choice of LOP/Architectural Design/ materials/ machines/equipments.

I wish to place on record the technical input on the part of Dr. Pradeep Chaturvedi (Vice-Chairman,FIE) and the efforts put in by Shri V.K.Rokade (Retd. ADG TD), Shri A.K.Garg (CE-CDO), Shri R.K. Kaushal (CA-NDR), Shri S.K. Chawla (CE-PEWZ), Ms Usha Batra (CA), Shri Sanjay Pant (Director -BIS), Shri Manu Amitabh (SE-PWD), Shri P. Bhagat Singh (SE-IPB), Shri Shishir Bansal (SE-PWD) and Shri Mukesh Kumar (SE-CDO) and his team of officers in CDO Unit in finalising the CPWD Guidelines for Sustainable Habitat.

The downloadable copy of CPWD Guidelines for Sustainable Habitat shall also be uploaded on CPWD website (www.cpwd.gov.in) very soon and its soft copy shall be updated on regular basis to facilitate planning and field officers of the Department.

(V.K. Gupta)
Director General
CPWD

New Delhi

सत्यमेव जयते

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PREFACE

The Central Public Works Department (CPWD) is a 159 year old institution and is the principal agency of the Government of India responsible for creating assets and providing comprehensive services including planning, designing, construction and maintenance of office & residential buildings as well as other structures of various ministries and departments of Government of India and other autonomous bodies and public sector enterprises. Its activities are spread throughout the length and breadth of the country.

CPWD has been a pioneer in construction industry with regards to sustainability approach as being the first to prohibit use of wood in construction work and playing a lead role in use of fly ash. CPWD is also committed to buildings conforming to minimum 3 star rating in all its projects reinforcing its outlook to environment friendly construction.

Sustainable development meets the needs of the present without compromising the needs of future generations. Keeping this aspect in view, CPWD Guidelines for Sustainable Habitat have been prepared. The guidelines are based on reports of National Mission on Sustainable Habitat by Ministry of Urban Development and draft code on "Approach to Sustainability" as part of NBC 2005. The guidelines are intended to be used by CPWD architect/engineers in day to day decision making process with regard to use and evaluation of materials and technology on sustainability parameters.

LEEDS and GRIHA are primarily building rating systems. They are generally silent on comparative evaluation of different green materials and technologies nor do they help in cost-benefit analysis, often confounding the field engineers'/architects' decision process. The problem is complicated by the fact that often, there are trade-offs in competing green qualities of different materials. CPWD engineers and architects have felt the need for specific guidelines and specifications for the day to day decision making process with regard to use and evaluation of materials and technology.

The need of the hour therefore, is to approach towards appraisal of sustainability of a built habitat in a more rational and holistic way. The first step in building sustainable habitat is to choose sustainable building material. With the experience of CPWD in use of green materials over a period of time, attempt has been made to formulate Sustainability Index for Building Materials. The parameters listed in the index are intended to act as guidelines to the practitioners in exercising their engineering judgement holistically and objectively relating to built environments, considering functionality and required comfort level. The proposed building index is not a substitute to GRIHA or LEEDS which deal with building as a whole, whereas CPWD Index is material specific. The proposed Index is not an absolute scale. It is merely a set of criteria on which relative judgement can be made between two materials of same product category with regards to sustainability.

The guidelines have been divided into four parts :-

1. Guidelines on Architectural Design and Layout.
2. CPWD Sustainability index and Guidelines for materials.
3. Guidelines for selection of equipment for Electrical and Mechanical Services for sustainable buildings.
4. Guidelines on reuse and recycling of construction and demolition waste.

The objective of CPWD guidelines on sustainable habitat is to help the Architect/ Engineers while taking decision on choice of LOP/Architectural Design/ materials/ machines/equipments. Our site engineers are required to be dependent on the green building consultant alone. These guidelines and sustainability index attempts to fill this void. Based on the experience gained in executing Indira Paryavaran Bhawan Project and others, these guidelines will educate the field engineers on parameters that need to be considered while choosing any material. Since these parameters are matching with building rating systems, it will also help the field engineers in securing points in those rating systems as well.

The example considered in CPWD sustainability index is also suggestive and not exhaustive in nature. In the sustainability index, various parameters and their weightage have been decided based on experience gained in Indira Parayaran Bhawan Project and other projects.

I am grateful to Shri V.K. Gupta, Director General, CPWD for reposing trust in me to undertake this work and express my deep appreciation to Shri V.K.Rokade (Retd. ADG TD), Dr. Pradeep Chaturvedi (Vice-Chairman FIE), Sh. A. K. Garg (CE-CDO),Shri R.K. Kaushal (CA-NDR), Shri S.K. Chawla (CE-PEWZ),Ms. Usha Batra (CA),Shri Sanjay Pant (Director-BIS), Shri Manu Amitabh (SE-PWD), Shri P. Bhagat Singh (SE-IPB), Shri Shishir Bansal (SE-PWD), Shri Mukesh Kumar (SE-CDO), Shri Sanjay Kumar (EE-CDO), Shri Abhishek Gopal (AEE-CDO) and various other officers / staff of CDO Unit who made their sincere efforts in finalising the CPWD Guidelines for Sustainable Habitat.

Though every effort has been made sincerely to prepare the guidelines correctly. However, if any discrepancy is found, it may be brought to the notice of Chief Engineer(CDO). Feedback are also invited for further refinement of the guidelines.

(Diwakar Garg)

Place: New Delhi **Spl. DG (HQ), CPWD**

CONTENTS

Part-I

Guidelines for Architectural Design & Layout

1. Scope

1.1. These guidelines broadly covers the parameters required to be considered for planning & design of buildings relating with respect to sustainable development.

2. Approach to Sustainability

2.1. The design process plays a significant role in creating built environment respecting all principles of sustainable development.

2.2. The various climatic zones like hot-dry, warm-humid, composite, temperate and cold climates as well as sun path movements and annual wind directions along with rainfall are the vital statistics data which need to be considered while designing a project.

2.3. The building envelope creates harmonious development when neighbourhood poses one of the biggest challenges in selection of building materials, technologies and practices. It may be a combination of natural and man-made materials with least embodied energy and also leading to use of renewable resources. The trade-off between choice of the materials and technologies and their effect on environment has to be balanced. As a holistic approach, all efforts should be made towards:

a. Encouraging and harnessing building materials out of agricultural, industrial and bio-wastes.

b. Environment-friendly and cost-effective.

c. Making building construction more indigenous, more adaptable to climatic zones of India.

d. Encouraging the use of traditional technologies and local vernacular architecture and construction practices which may be blended with the modern technology applications.

3. Energy Efficient Design and Processes

3.1. Adopt passive architectural design strategies to create climate sensitive buildings, with higher thermal comfort and lower energy consumption.

3.2. Effective site planning through orientation of the building according to sun angle, and wind direction.

3.3. Reduce the hard paved areas on the site and try to retain the mature trees as many as possible.

3.4. Identify the climatic zone of the site according to the NBC-2005 and then prepare the design strategies.

3.5. Use of low energy or passive heating or cooling measures help to ensure the overall thermal comfort of the building.

4. Site Design and Development

4.1 Establish if there are any protection areas such as floodplains; forest department areas; water bodies such as sea, lakes, rivers, wetlands, tributaries and/or streams; public parks and recreation areas (unless otherwise used for the purpose of the park); and agricultural land (unless serving and agriculturally related purpose such as storage, 1.1. processing, transport, etc.) and demonstrate that no critical natural resource is impacted by the project and/or dredging operations;

4.2. Establish the degree to which the existing soil at site and hydrology has been disturbed prior to development and demonstrate various site erosion protection measures taken including measures to preserve top soil and existing vegetation, minimize soil disturbance.

4.3. A well-planned and optimally oriented building relates well to its site and the climate. This maximizes opportunities for :

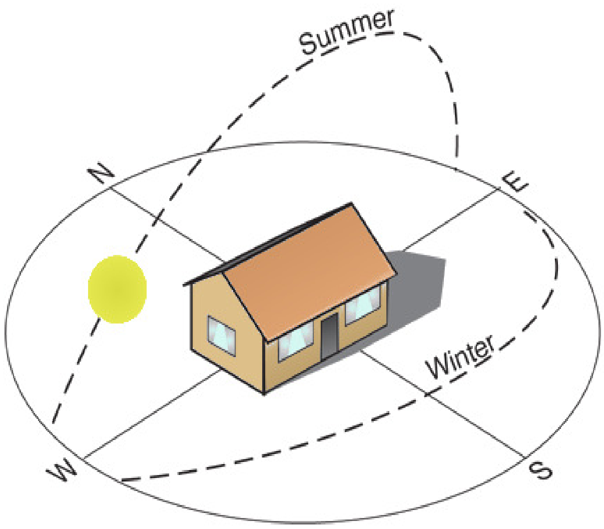
- 4.3.1. Passive solar heating when heating is needed.
- 4.3.2. Solar heat gain during winters.
- 4.3.3. Natural ventilation as needed.
- 4.3.4. High-quality day lighting throughout the year.

4.4. Carefully planned building placement shall also minimize storm water runoff, habitat disturbance, protect open space, and reduce the risk of soil - erosion.

4.5. Trees are an important factor in passive solar design as they can both provide needed shade on a summer day and natural light when it is needed most. Deciduous trees planted on the south side will lose their leaves in the winter and allow natural light to enter the house, while evergreen trees planted on the north side will provide shade from the summer sun.

5. Building Orientation and Shading

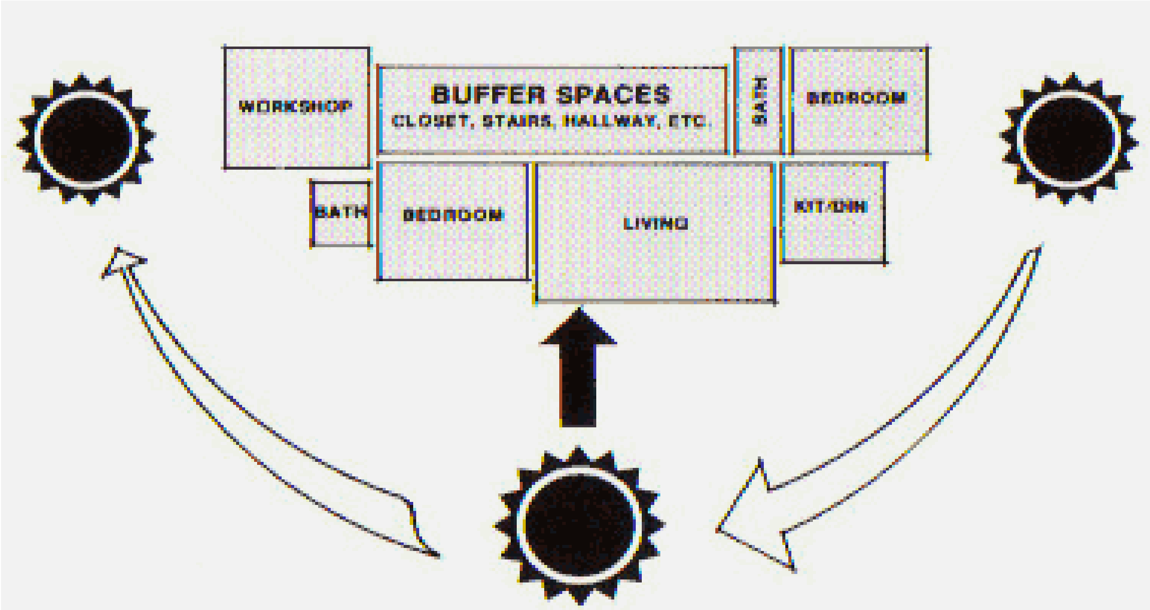
5.1 The building shall be oriented with the long sides facing north and south whenever the site and location permit such orientation.



5.2. Balconies and open terraces should be built on the south side of the house, where direct sunlight will permit their use for more hours during the day and more days during the year. Likewise, the garage, store rooms and other areas that are less frequently used should be situated at the northern part of the house, where they will act as buffers against cold winter winds.

5.3. Another environmental factor that should be considered in the planning of building orientation and positioning is prevailing winds, which are the winds that blow predominantly from a single, general direction over a particular point. Data for these winds can be used to design a building that can take advantage of summer breezes for passive cooling, as well as shield against adverse winds that can further chill the interior on an already cold winter day.

5.4. For maximum solar gain, a building should be located near the site's southern boundary to reduce the shading from neighboring properties, and also provide sunny outdoor space. However, the best location for solar access will vary from site to site depending on site shape, orientation and topography, and shading from trees and neighboring buildings.



5.5. There is a provision for external shading of the south façade during the peak summer season, and provisions are required for providing vertical shading to prevent direct solar radiation and glare due to low altitude sun angles, especially on the eastern and western facades.

5.6. There is a protection for the building envelope against thermal losses, drafts and degradation by natural elements such as wind and materials such as dust, sand, snow, rainwater, hail, etc. Orient buildings and design shading devices to optimize use of solar energy.

6. Design strategies for Day lighting

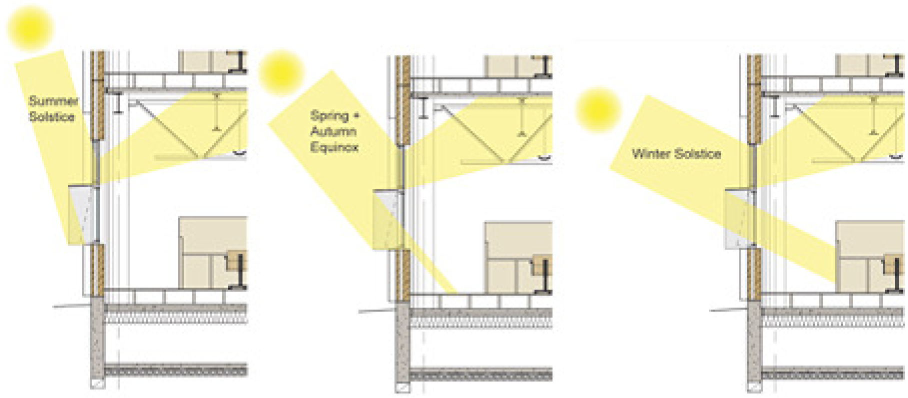
6.1. This is the most important aspect as it while designing openings the natural daylight, will promote some amount of heat gain as well, hence the challenge is to reduce the heat gain while ensuring the adequate natural day lighting.

6.2. Daylight comprises both skylight (diffuse light from the sky), and sunlight (direct beam radiation from the sun). It is constantly changing according to the time of day, time of year and the weather and it is this variability that provides interest to interiors and helps to create satisfying places to work and live.

6.3. East & west directions have highest insolation values, while south & north have the least. Therefore more windows can be provided on these two directions to reduce the insolation values.

6.4. Utilize skylights, clerestory windows and fanlights to supplement daylight access through regular windows. Promote double height spaces in areas where daylight access is limited, to assist daylight penetration into living areas and private open spaces.

6.5. Shading of window can drastically reduce the heat gain through sun. The shades along the glass of window define the net reduction in the direct heat gain through solar radiation. Therefore after appropriate orientation of the building and shading device, select a glass with low SHGC value, to reduce the heat transfer.



6.6. The size of the window determines the amount of day light and solar radiation coming inside. Therefore it is advisable to optimize the design of the window as per the climatic zones and as per the wall window ratio.

7. Design strategies for Building Envelope

7.1 Design the building envelope as such that the overall heat gain through it is within the acceptable limits, thus reducing the energy consumption required by HVAC system.

7.2 Design the building envelope, the wall sections, outer frame with respect to analyzed thermal energy efficiency of the building.

7.3 The thermal energy efficiency of the building depends upon following parameters:

7.3.1 External heat gain factors

7.3.1.1 Solar Heat Gain Coefficient (SHGC): SHGC refers to the ratio of the solar heat that passes through the glazing to the total incident solar radiation. The lower the SHGC, the lesser the direct incident heat gains from the glazing surfaces. ECBC sets the maximum permissible SHGC values for different climatic zones:

Climate	WWR ≤ 40%	40% < WWR ≤ 60%
	Maximum SHGC	Maximum SHGC
Composite	0.25	0.2
Hot and Dry	0.25	0.2
Warm and Humid	0.25	0.2
Moderate	0.4	0.3
Cold	0.51	0.51

7.3.1.2 Projection Factor: Since the total incident radiation on a fenestration can be reduced by providing shading devices, their impacts are considered while calculating the effective SHGC in ECBC. This is done by determining the projection factors and corresponding M-factors and using them in calculating the adjusted SHGC.

7.3.1.3 Projection Factor is the ratio of the horizontal depth of the overhang divided by the distance between the bottom of overhang and window sill level.

$$P = H/V$$

7.3.1.4 U - Value: is defined as the amount of heat that gets transmitted through a unit area of a material for a unit difference in temperature. The lower the U-Value of the material, the lesser the heat transfer, and better the thermal efficiency. ECBC recommends the following U-values for glazing:

Climate	Maximum U-factor (W/sq.m.-°C)
Composite	3.3
Hot and Dry	3.3
Warm and Humid	3.3
Moderate	6.9
Cold	3.3

7.3.1.5 Visible Light Transmittance (VLT): Visible light transmittance refers to the ratio of visible light that is transmitted through the glazing as compared to the total visible light falling on it. The higher the VLT, the more the daylight comes into the room.

7.3.2 Internal heat gain factors

7.3.2.1 LPD Level: - stands for Lighting Power Density and may be taken as total heat that is generated inside the building through an artificial lighting system.

7.3.2.2 EPD Level: - It stands for Equipment power density. The more efficient the equipments, the lesser the EPD levels.

7.3.2.3 Building Occupancy: - Define an optimum building occupancy, as an over-crowded building increases the temperature and humidity levels very high.

8. Design strategies in a Cold climate

8.1. Design according to the site slopes, and Orientation should preferably be in north - south direction i.e. longer walls should face north & south to receive more solar heat during winter months.

8.2. Glazing windows up to 25% floor area may be provided. Double glazing is preferable to avoid heat losses during winter nights.

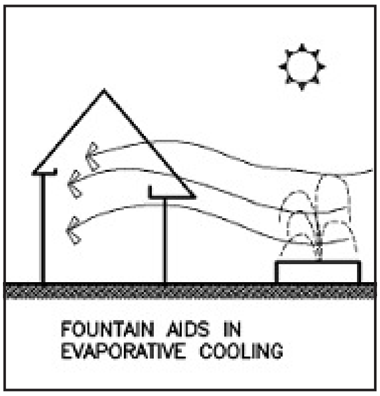
8.3. Adopt Trombe walls as they are a very useful passive heating system. They require little or no effort to operate, and are ideal for cold climates.

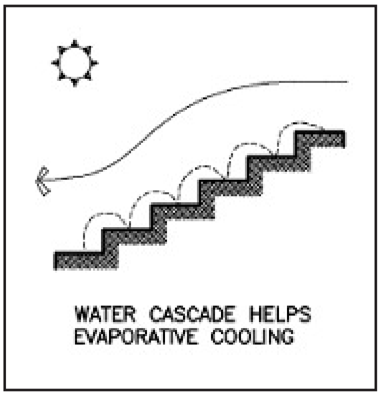
8.4. Sunspaces are equally simple and silent, and can allow views. Rooms heated by a Trombe wall or sunspace often feel more comfortable than those heated by forced-air systems, even at lower air temperatures, because of the radiantly warm surface of the wall.

8.5. Allow maximum solar heat gain inside the building which will allow natural daylight during the day but intelligently cut the cold waves during the night time, if possible provide air lock to prevent heat loss.
8.6. Provide glass covered atrium and central spaces.
8.7. Installation of solar panels to harness the solar energy is a good option.

9. Design strategies in a Composite climate

9.1. Plan or site plan the building to increase the cross ventilation of the internal rooms by providing them around the courtyard.
9.2. Plan water bodies on the bigger sites, wherever possible, so that hot air can pass over them.
9.3. Provision of cavity walls, terrace gardens, green roof, light shelves to be increased in building planning
9.4. Provision of roof insulation using insulation material, china clay or clay pots is advisable.
9.5. Reduce heat gain in the building through building envelope.
9.6. Wind towers can work very effectively in this type of climate, where daily variations in temperatures are high with high temperatures during the day and low temperatures during the night.
9.7. Increasing the rate of ventilation during cooler parts of the day or night-time and during the humid periods is a necessity in composite climatic areas.
9.8. Water bodies like ponds and lakes act as heat sinks and can also be used for evaporative cooling.





9.9. Cooling measures such as geothermal cooling and earth tunnel cooling is an effective way of cooling which can be utilized as a passive architectural means.

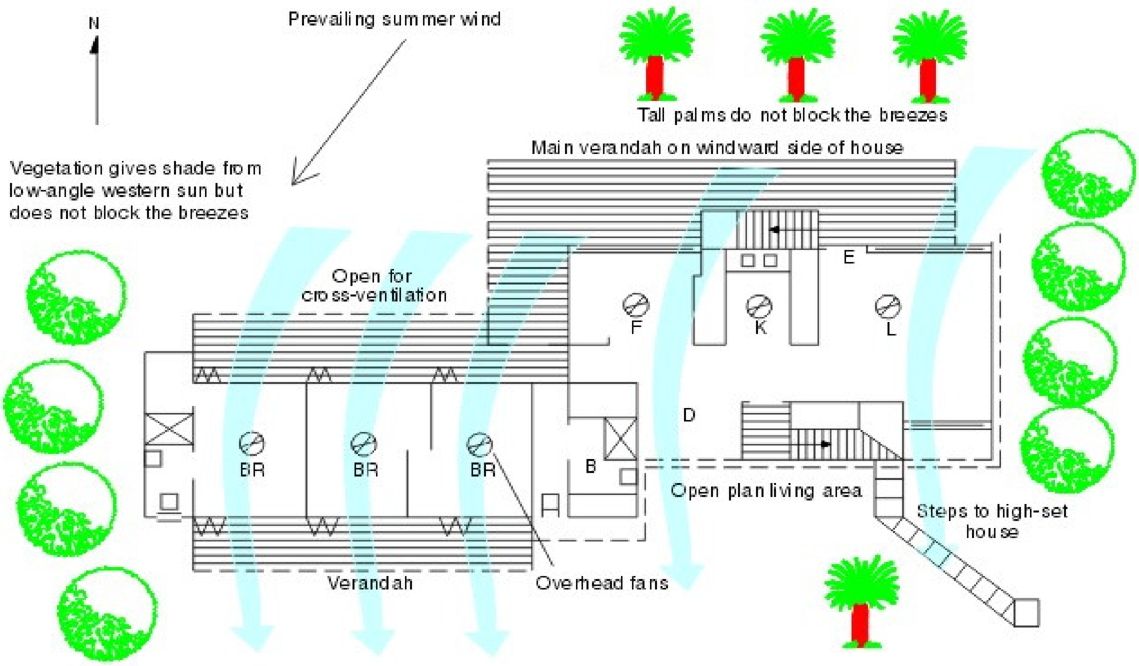
10. Design strategies in a Warm & Humid climate

10.1. Orientation should be preferably in North-South direction for habitable rooms i.e. longer walls should face north & south so that shorter sides are exposed to direct sunlight.
10.2. Provide maximum cross ventilation in the building, hence orientation of the building in this zone is very important and is based on the direction on the winds.
10.3. Large openings should be positioned on windward and leeward direction. Openings should be provided with suitable protection like sunshades, chhajjas etc. from Sun and rain.

10.4. Windows area should be 15 to 20 percent of floor area. The sill height of windows should be low. Fixed windows should be avoided.

10.5. Internal distribution of the spaces to be carried out such that the buffer spaces like the store rooms, staircases, toilets etc are located on the eastern and western facades.

10.6. Solar chimneys can be provided for improving the ventilation of the building. Ventilation can also be improved by providing stack effect.



DESIGN FOR A WARM/HOT HUMID CLIMATE

10.7. Exposed surfaces like roofs and terraces need be insulted with good insulation material.

11. Design strategies in a Hot & Dry climate

11.1. Longer walls of building should face north & south. Non-habitat rooms can be located on outer faces to act as thermal barrier. Preferably, the kitchen should be located on leeward side of the building to avoid circulation of hot air and smell from the kitchen.

11.2. The day lighting of architectural space utilizes diffuse light from the sky dome, direct beam radiation from the sun, and reflected light from adjacent object surfaces.

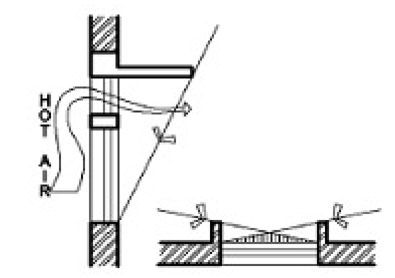
11.3. Large openings with heavy shutters should be provided on northern and western faces as light coming from north is always diffused and indirect, also direction of breeze, which is from west at most of the places, enters from opening on west side.

11.4. Windows area should be at least 15 to 20 percent of floor area.

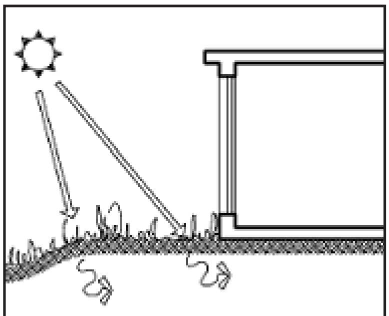
11.5. Internal courtyard caters for cross ventilation & thermal buffer. Suitable radiation barriers in the form of canopies, chhajjas, long verandahs etc. should be provided on the west side of the building. Sufficient number of ventilators close to the bottom of slab should be provided.

11.6. Wind towers can work very effectively in hot and dry types of climate, where daily variations in temperatures are high with high temperatures during the day and low temperatures during the night.

11.7. Preserve the thermal integrity of massive walls and insulated roof structures, penetrations are usually minimized.
11.8. In hot dry climates interior surfaces should be light colored but not so bright as to cause visual discomfort.
11.9. Sky lighting is a unique opportunity for combining natural ventilation options with lighting. Operating skylights located in the upper reaches of the space can utilize natural convection to remove excess heat.



PROPERLY DESIGNED CHAJJAS AND FINS HELP TO KEEP THE INTERIORS COOL



GRASS ABSORBS HEAT AND MINIMISES RERADIATION

12. Design strategies in a Moderate climate

12.1. Internal distribution of the spaces to be carried out such that the buffer spaces like the store rooms, staircases, toilets etc are located on the eastern and western facades.
12.2. Living areas like bedrooms may be located on the eastern side to allow for heat penetration in the mornings, and an open porch on the south east side allows heat gain in the winters while providing for shade in the summers. The western side should ideally be well-shaded.
12.3. Design of the openings is according to the local wind patterns.
12.4. Design of the building and orientation is according to the site topography.
12.5. Provide light colored external surfaces.
12.6. Improve the cross ventilation either through solar chimney or through stack effect.

13 Reduction in Overall Embodied Energy of Building Materials

13.1 Embodied energy is total energy consumed in mining, processing, manufacturing, transportation and installation of each unit of a material. The higher the embodied energy of a building, the more is the emissions.
13.2 Use low energy strategies / materials for constructions for floor slabs, roof slabs and wailing systems in order to reduce the overall embodied energy of the building as compared to the conventional RCC structure.
13.3 Promote the use of low energy materials in interiors to maintain indoor air quality through the use of low VOC paints.
13.4 Ensure all the sealants and adhesives used are water based rather than solvent based or have low solvent content. Most construction adhesives offers adequate bond strengths in water based varieties. While solvent based products such as urethanes and butyls should preferably not be used indoors, sealants used for exterior do not pose any concern.

13.5 More than 70% of total material used in the building interiors should be low energy.

13.6 Wood is not considered under this category while Bamboo, coir etc are low energy materials.

13.7 Materials with a longer life relative to other materials designed for the same purpose need to be replaced less often. This reduces the natural resources required for manufacturing and the amount of money spent on installation and the associated labor.

13.8 Reusability is a function of the age and durability of a material. Very durable materials may have many useful years of service left when the building in which they are installed is decommissioned, and may be easily extracted and reinstalled in a new site.

13.9 The biodegradability of a material refers to its potential to naturally decompose when discarded. Organic materials can return to the earth rapidly, while others, like steel, take a longtime.

14 Integrated Water Management

14.1 Integrated and sustainable water management focusing on least anthropogenic water discharge from human activities should be pursued.

14.2 The use of water conservation fixtures, landscaping, rain water harvesting, aquifer recharging and waste-water recycling need to be given due consideration.

14.3 Involve use of efficient building and plumbing services components and fixtures tailor-made to meet sustainability objectives and creating sufficient awareness among the users of building facility and its services, during the occupancy stage.

14.4 Ensure potable quality of water for drinking and washing as per the prescribed standards and to ensure that treated waste water is meeting the desired standards for reuse or disposal.

14.5 Minimize the consumption of mains supply potable water and minimize the volumes of urban storm water run-off.

14.6 Consider natural storm water filtration and absorption schemes which employ engineered, landscaping devices such as swales, rain gardens and infiltration ponds.

15 Solid Waste Management

15.1 Ensure maximum resource recovery and safe disposal of wastes generated during construction and reduce the burden on landfill.

15.2 Minimize waste generation; streamline waste segregation, storage, and disposal; and promote resource recovery from waste.

15.3 At the time of the construction allocate separate space for the collected waste before transferring it to the recycling/disposal station and use different colored bins for collecting different categories of waste from the building.

16 Integrated approach to Water supply, water waste and solid waste Management

16.1 Adoption of treatment and processing before disposal and adopting waste to energy technologies. It will not only reduce the quantity of wastes but also improves its quality to meet the required pollution control standards.

Part-II

CPWD Sustainability Index & Guidelines for Materials

1. CPWD Sustainability Index

The options for sustainable material available for any kind of work (like walls, partitions, roofing, fenestration etc) are plenty and have been listed out in the section ahead. Each material can be evaluated on a set of criteria to determine if the use of the material is sustainable. Each criterion would have a trade-off with other criteria in the set. For example a material with low embodied energy would not necessarily be low cost too or might not be readily available. The need is to classify and prioritise each material within a product category with an eye on the concept of sustainability. For the purpose, CPWD sustainability index as described can compare two or more available materials for same product category in sustainability parlance. Such comparison may be helpful to choose which material will lead to sustainable habitat construction out of different available materials. For eg, using this index a site engineer can choose between UPVC frames and Aluminium frames, as which material will lead to sustainable habitat construction and hence adopt the same.

The proposed parameters and their weightage is based on CPWD's experience with working on these materials and emphasis laid on in LEEDS and GRIHA rating systems. Thus, a material which is performing better in this index will automatically help in securing points in various building rating systems. Proposed parameters and their weightage for CPWD Sustainability Index of materials are as under:

S.No.	Proposed Parameter	Weightage
1	Recycled content	10
2	Embodied Energy	10
3	Rapidly Renewable	5
4	Locally Available Material	10
5	Functional Life Period	10
6	Capital Cost	10
7	Maintenance Cost	10
8	Construction Waste Management	5
9	Flyash Content	10
10	Reduced Weight	5
11	Reduced Time of Construction	5
12	Toxicity/Indoor Air Quality/Safety	10
	Total Points	100

2. Details of Proposed Parameters:

2.1 Recycled content: Use of recycled material is a factor of huge importance with regards to sustainability. Recycled content refers to the amount of recycled material that can be used while producing the product. For recycled content, the rating can be based on a relative scale, with a maximum of 10. For example, within the product category of "Window frames", if we have to compare between Aluminium window frames, Steel window frames and UPVC window frames, following procedure may be adopted:

1 List down the recycled content of the individual material. This recycled content may be obtained from the manufacturer. For ex, UPVC window frames have a recycled content of 70%, Steel windows, 60% and Aluminium window frames have 50%.

2 The material with highest recycled content shall be given a highest rating of 10. In our example, UPVC window frames shall be given a rating of 10.

3 The material with second highest recycled content shall be rated in the scale of 10. In our example, Steel windows have a second highest recycled content, hence the rating shall be 10*60/70 = 8.6.

Similarly, Aluminium window frames shall have a rating of 10*50/70 = 7.

2.2 Embodied Energy: Embodied energy of a material refers to the total energy required to produce that material, including the collection of raw materials. This includes the energy of the fuel used to power the harvesting or mining equipment, the processing equipment, and the transportation devices that move raw material to a processing facility. The ratings for embodied energy can be done for different materials within the same product category on a relative sale of 10. 10 rating shall be awarded to material with lowest embodied energy. Other materials shall be rated relatively as in 2.1.

Classification of Materials Based on Energy Intensity

Sl No.	Category of material	Energy intensity (GJ/t)	Examples
i)	Very High energy	>50	Aluminium, stainless steel, plastic, copper, zinc.
ii)	High energy	5-50	Cement, steel, glass, bitumen, solvents, cardboard, paper and lead.
iii)	Medium energy	1-5	Lime, gypsum plaster board, burnt clay brick, burnt clay brick from improved vertical shaft kiln, soil cement block, aerated block, hollow concrete block, gypsum plaster, concrete block, timber, wood products, particle board, medium density fiber board, cellulose insulation, *in- situ concrete.*
iv)	Low energy	<1	Sand, aggregate, fly ash, cement stabilized earth block, straw bale, bamboo, stone.

NOTES

1 While comparing embodied energy of building materials, the total quantity by mass of the material times the embodied energy value per unit mass (energy intensity) of the material to be installed for same surface area of the building may be compared.

2 The values given in the table are comparative values, and in case of substantial difference in the transportation component of the materials in question, the same should also be taken into account.

2.3 Rapidly Renewable: Rapidly renewable materials are typically those which are made from plants that are harvested in a 10 yr or shorter cycle. Intention is to reduce the use of finite raw materials and long cycle renewable materials and promote the use of products obtained from rapidly renewable raw materials.

Rapidly Renewable	Weightage
Yes	5
No	0

2.4 Locally available material: Intention is to promote utilisation of materials that are produced and manufactured locally and hence reduce the environmental impact of transportation. Mechanical, electrical, plumbing items and speciality items like elevators need not be considered.

The rating can be given based on the location of construction site. Among one product category, the material which is produced near the site shall be given preference. For ex, at a construction site near the stone mining area, stone as partition material should be given higher rating than brick which may be required to be transported from far away distances.

Local Availability of Material	Weightage
Manufacture and Extraction within 400 kms	9-10
Manufacture within 400 kms & Extraction beyond 400 kms	7-8
Manufacture beyond 400 kms & Extraction within 400 kms	5-6
Manufacture and Extraction both beyond 400 kms	0-4

2.5 Functional Life Period: Functional life period means the time duration in years for which the material is expected to perform its functional requirements satisfactorily. When comparing materials, the one having longer functional life will get more ratings over the material having lesser functional life. Assuming the life cycle of building as 90 yrs, following rating can be adopted:

Life of Material (yrs)	Weightage
>80	10
70-80	9
60-70	8
40-60	7
30-40	6
20-30	5
10-20	4
Upto 10	1-3

2.6 Capital cost: It is the one-time cost incurred initially on any material. Capital cost includes installation cost too. This has to be assessed relatively for a category of materials with max weightage of 10. Higher the capital cost, lesser will be the rating for a material.

2.7 Maintenance cost: It is the approximate cost incurred on maintenance of material over its functional life period on yearly basis. Higher the cost, lesser will be the rating for a particular material. Maintenance cost for each material shall be found out on yearly basis. This cost shall be irrelevant to the functional life period of building as a whole. The rating shall be as explained in 2.6 for capital cost with the cheapest material rated as 10.

2.8 Construction Waste Management: The material that will lead to the lesser burden on landfill in terms of disposal of waste generated during construction should be given higher ratings. Some toxic wastes that are dealt with in construction site are Asbestos products, tar, lead, plastics, paints, mercury containing devices etc.

Relative Waste Management	Weightage
High	5
Medium	3
Low	NIL

2.9 Flyash content: Material utilising flyash as its ingredient should be given higher rating. Flyash must be used in concrete, mortar etc. This factor shall not be considered for product categories where flyash mixing is not possible ex, door window frames, paints etc.

Flyash Content (%)	Weightage
>60	10
50-60	9
40-50	8
30-40	7
20-30	6
15-20	5
10-15	4
0-10	0-3

2.10 Reduced Dead weight: Materials within a product category that has lowest Dead weight shall be given preference. In one product category, the material with lowest dead weight per unit volume shall be given a rating of 5. The other heavier materials shall be scaled relatively with procedure as followed in 2.1. The objective is to promote use of lighter materials thus reducing the overall energy requirements of buildings including lesser transportation effort, lesser lifting effort etc. The lesser weight of the materials results in reduced dead weight of the building which optimises building design and reduces quantity of structural materials.

2.11 Reduced Time of Construction: Within a product category, any material that has the capability to reduce the time of construction shall be given precedence over the one which takes longer time. The objective is to promote innovative concepts like prefab material, modular construction etc. When any material within a product category offers time advantage it may be given a rating of 5 else zero rating shall be given.

2.12 Toxicity/Indoor Air Quality/Safety: The objective of this parameter is to give due consideration to materials which are less inflammable, less hazardous, fare better against corrosion and are less reactive to environmental conditions with respect to emission of toxic gases and are better from health point of view of occupants. This point is specifically relevant for finishing materials like paints which can be toxic in nature. VOC content should be kept as low as possible for paints.

Example: Given below is relative evaluation of Aluminium and UPVC window frames based on above Sustainability Index. The marks given to parameters as well as materials for relative evaluation are as per CPWD practices/experience.

S.No.	Proposed Parameter	Total Marks	Aluminium	UPVC
1	Recycled content	10	7	10
2	Embodied Energy	10	5	10
3	Rapidly Renewable	5	0	0
4	Locally Available Material	10	8	8
5	Functional Life Period	10	10	5
6	Capital Cost	10	10	5
7	Maintenance Cost	10	8	8
8	Construction Waste Management	5	5	5
9	Flyash Content	10	0	0
10	Reduced Weight	5	5	4
11	Reduced Time of Construction	5	0	0
12	Toxicity / Indoor Air quality/Safety	10	9	6
	Total Points	100	67	61

Explanation of example of Sustainability index

The ratings in the example of comparison between Aluminium and UPVC windows has been derived on the following basis:

1) **Recycled Content:** Recycled content for Al = 50%, Recycled content for UPVC = 70% Thus, Rating for UPVC = 10 (highest recycled content)& Rating for Aluminium = 50*10/70 = 7.

2) **Embodied Energy:** For Aluminium = 6000MJ/unit, For UPVC = 2980 MJ/unit Therefore, Rating for UPVC = 10 (Lowest embodied energy), And, Rating for Aluminium = 2980*10/6000 = 5

3) **Rapidly Renewable:** Both Aluminium and UPVC are obtained from raw materials which are NOT rapidly renewable. Thus, both shall be awarded ZERO marks in this category as per table in 2.3.

4) **Locally Available Material:** In the example, it is assumed that construction site is in Delhi.

   Aluminium windows frames are manufactured in the peripheral industrial areas of Delhi but its extraction is from the state of Orissa ie beyond 400 kms from Delhi. Thus it has been awarded 8 marks as per Table 2.4.

   UPVC window frames are manufactured in Rewari (within 400 kms) and raw material is obtained from beyond 400 kms. Therefore UPVC shall also be rated as 8 in the table.

5) **Functional Life Period:** Functional life period for Aluminium window frame is >80 yrs hence 10 rating as per Table 2.5. For UPVC, it is 25 yrs (approx) and hence has been rated as 5.

6) **Capital cost:** As per general market survey, cost of UPVC window is 2 times that of Aluminium window frame. Therefore, Al rating = 10

   And UPVC rating = 10/2 = 5.

7) **Maintenance cost:** Both Aluminium and UPVC are maintenance free and hence have been provided equal rating on the higher side of scale of 10.

8) **Construction Waste Management:** Both UPVC and Aluminium after their service life will be recycled and will not lead to burden on Landfill. Hence both have been awarded 5 marks as per table 2.8.

9) **Flyash Content:** Both Aluminium and UPVC have no flyash content hence have been rated zero as per table 2.9.

10) **Reduced Dead Weight:** Aluminium windows are lighter than UPVC windows. To bring the lightness of Aluminium window into picture it has been rated as 5 and UPVC window as 4. While comparing for other materials, one unit of all materials in question may be weighed and tallied to find out the exact rating.

11) **Reduced time of Construction:** Neither Aluminium nor UPVC will lead to Reduced construction time hence both have been awarded zero.

12) **Toxicity, Indoor Air Quality, Safety:** 4 factors may be considered for windows, Corrosion (2 pts), Durability (2 pts), Warping (2 pts) and Fire resistance (4 pts).

An aluminium window frame can be awarded 1, 2, 2, 4 respectively in above 4 categories. UPVC Window can be awarded 2, 1, 1, 2 respectively.

The points are awarded based on the fact that UPVC is better resistant to Corrosion than Aluminium where as Aluminium is better performer in Durability, warping and Fire resistance criteria.

Thus total point for Aluminium = 1+2+2+4 = 9 (out of 10)

Total point for UPVC = 2+1+1+2 = 6 (out of 10)

3 Materials

3.1 Materials and Recommended Sustainable Alternatives

For quality requirement of building materials reference shall be made to National Building Code of India: Part 5 and to CPWD specifications Volume 1. Following are the alternatives to conventional material that may be considered subject to conforming to structural requirements and performance.

3.1.1 Mortar

The following sustainable options may be considered for appropriate applications:

a) Lime mortar
b) Cement mortar
c) Mud mortar
d) Lime sand mortar
e) Lime pozzolana mortar

NOTE - There are other technologies and materials available locally which use no cement and use flyash and binding agents. These options may be used if performance parameters are met.

3.1.2 Cement concrete Recommended alternatives to conventional concrete:

a) Use of pozzolanas and other mineral admixtures for cement replacement in cement concrete and other cement matrix products
   1) Use of fly ash and slag in cement concrete - (DSR Item no 5.40, 6.32, 6.34, 6.37, 6.42, 16.51, 16.52, 6.36, 6.45, 6.46)
   2) Rice husk ash (RHA) - May be used for part replacement of cement.
   3) Ready mixed concrete (RMC) - (RMC Concrete, DSR Item no 4.19)
   4) Geopolymer concrete - Designed with pozzolonas and slag. It has good resistance to chloride penetration and acid attack.

a) Use of recycled aggregate

c) Precast/prefabricated/partially prefabricated concrete elements - (Precast Cement Concrete, DSR Item no 4.5, 4.6, 4.7, 4.8, 4.9, Precast RCC elements, DSR Item no 5.12, 5.13, 5.14, 5.15, 5.16, 5.17, 5.36)

d) Use of light weight concrete

   1) Preformed foam concrete - Preformed foam concrete may be considered for use for the levelling of floors, sprayed onto horizontal surfaces or in hollow cavities as light weight filler.

   2) Ferrocement

e) Use of light weight aggregates in concrete (Vermiculite in light weight plaster, DSR Item no 4.19)

f) Commonly used masonry concrete blocks:

   1) Solid and hollow concrete blocks - (Hollow Blocks, DSR Item no 4.8, solid blocks, DSR item no 4.7)

   2) Autoclaved cellular (aerated) concrete blocks

   3) Lightweight concrete blocks

   4) Preformed foam cellular concrete blocks

   5) Concrete stone masonry blocks

3.1.3 Burnt clay bricks and tiles

The following other types of bricks may also be used as sustainable alternatives:

1) Hollow/perforated bricks
2) Low and medium-fired bricks
3) Burnt clay flyash bricks
4) Flyash lime bricks
5) Red mud burnt bricks
6) Lato bricks

3.1.4 Stone (Random Rubble Masonry, DSR Item no 7.1 to 7.5)

3.1.5 Timber

3.1.6 Bamboo (Bamboo Jaffery, DSR Item no 9.110)

3.1.7 Plastics (Door Frames, DSR Item no 9.118)

Other options where use of plastics may be considered for appropriate applications, may be:

1) Rice husk plastic wood
2) Natural fibre composite panels and door shutters
3) Fibre-reinforced plastic (FRP)

3.1.8 Metals

3.1.9 Earth construction

Various options/considerations in this area are:

a) Adobe bricks
b) Adobe pouring construction
c) Compressed earth blocks (CEB)
d) Soil based building blocks

3.1.10 Cob walls

3.2 Surface Materials

3.2.1 Floor and floor coverings

Following are recommended for various floor covering materials which may replace conventional materials subject to compliance of performance requirements:

a) Finish concrete flooring - (Flooring, DSR Item no 11.3)

b) Resilient flooring (bamboo and linoleum flooring)

c) Terrazzo in-situ flooring and tiles - (Terrazzo Flooring, DSR Item no 11.9, 11.18, 11.19 Tile Flooring, DSR Item No 11.16)

d) Ceramic/vitrified tiles

e) Wooden flooring

f) Stones

3.2.2 External and internal wall finishes

Following are recommended from sustainability point of view subject to compliance:

a) Plaster -Features of various plasters having effect on sustainability are as follows:

1) Lime plaster

2) Cement plaster - (Cement Plaster, DSR Item no 13.1 to 13.17)

3) Cement-lime plaster -(Rough Cast Plaster, DSR Item no 13.19)

4) Gypsum plasters - (Neat Cement Punning, DSR Item no 13.18)

5) Clay plaster

6) Sulphur plaster

b) Mineral and fibre based sheeting/boards - Features of such boards having effect of sustainability are as follows:

1) Fibre cement sheets/boards (Gypsum Board, DSR Item no 12.52.3) (Non Asbestos Sheets, DSR Item no 12.12)

2) Calcium silicate sheet - (Calcium Silicate Sheet, DSR Item no 12.52) (Calcium Silicate Bricks, DSR Item no 6.35) (Calcium Silicate Board, DSR Item no 9.105.3)

3) Gypsum plaster board - (Gypsum Board ceiling, DSR Item no 9.133.3, 12.45.4)

c) Grit wash - (Grit wash, DSR Item no 13.72)

d) Paints and coating

e) Timber - Refer 2.2.6.

f) Stone cladding - (Stone work, DSR Item no 7.40, 7.41)

g) Metal composite panels (MCP)

h) Wallpapers

3.3 Building Fenestration and Detailing

3.3.1 Glazing

3.3.2 Door-window frame

- Use of stone frame should be preferred in the area where they are locally available as they provide an economical, durable, and termite proof frame.
- Metal frame although recommended for its durability, high recyclability, light weight and for larger spans, has high heat conductivity.
- Metal frames are required to be detailed with thermal break (low conductive material) to reduce their conductivity.
- Frames of plastic and aluminium can be made of profiles filled with foamed insulation of polyurethane to offset high heat conductivity.
- Plastic windows are usually made of unplasticized polyvinyl chloride (UPVC) stabilized by cadmium, lead and tin compounds and added colour pigments. All these products have very limited reserves, and cause high level of pollution during processing.
- The manufacture of an aluminium and UPVC door and window frame uses very high energy input than a timber door and window frame.
- Both UPVC and aluminium windows can be reused if they are initially installed for easy dismantling. Pure aluminium frames can be recycled.

3.4 Climatic Materials

3.4.1 Thermal insulation materials

Types of thermal insulation materials

a) Mineral wool -
   1) Glass wool - (False Ceiling, DSR Item no 12.52.4, 12.57)
   2) Rock wool
   3) Cotton
   4) Natural wool

b) Cellulose fibres - (Partition Board, DSR Item no 9.105.4)

c) Plastic - (Polyurethene, DSR Item no 12.56):
   1) Extruded polystyrene .
   2) Expanded polystyrene

d) Autoclaved aerated (cellular) concrete blocks - (In masonry, DSR Item no 6.39, 6.42, 6.46)

e) Preformed foam cellular concrete blocks.

f) Hollow concrete block - (Heat resistant tiles, DSR Item no 12.55)

g) Reflective Insulation materials

h) Perlite and pumice products (In plaster perlite, DSR Item no 13.78)

i) Vermiculite products - (In plaster vermiculite, DSR Item no 13.78)

j) Saw dust and wood shavings

k) Traditional techniques - Following vernacular techniques have generally been used effectively for thermal insulation of building in the country:
   1) Straw-bale insulation
   2) Inverted earthen pot insulation.
   3) Brick bat coba - (Brick Koba, DSR Item no 22.7)
   4) Mud phuska - (Mud Phuska, DSR Item no 12.16, 12.17)

l) Broken Ceramic mosaic tiles - (In flooring, DSR Item no 11.44)

m) Cavity wall insulation - (Cavity Wall, DSR Item no 6.6)

3.4.2 Covering or finishing materials for thermal insulation

These may include:

a) Weather Barriers - (Water Proofing Cemen Paint, DSR Item no 13.44, 14.64)

b) Vapour retarders - Eg.Laminated foil-scrim membranes and metal and plastic sheets.

3.5 Moisture and air regulating materials

Common air sealing materials include caulks, expanding foams, weather-stripping of doors and windows, gaskets, door sweeps. Another environment friendly technique is to use high recyclable moisture regulating materials like adobe brick and mud construction.

3.6 Water proofing materials

a) Cement based waterproofing products - (Relevant DSR Item nos 22.1, 22.2, 22.3, 22.7, 22.15, 22.16, 12.18, 12.17, 12.19, 12.20)

b) Plastic-Polymer products -Some examples are coal-tar, bitumen, ethylene propylene diene monomer (EPDM), polyurethane and PVC, which are briefly described below:
   1) Polymer modified bitumen - (DSR Item no 22.16 to 22.20)
   2) Polyurethanes/urethane membranes
   3) Thermoplastics (PVC) waterproofing membranes
   4) Asphaltic membranes

c) Brick bat coba

d) Bentonite clay

e) Other waterproofing membrane materials (Silicon used in paints, DSR Item no 13.47, 14.47)

Part-III

Guidelines for Selection of Equipment for Electrical & Mechanical Services for Sustainable Buildings

1. **Electrical Power** Saving Energy, utilizing minimum energy and reducing the losses and still achieving the desired qualitative services in the building contributes to a large extent towards sustainable development.

   The losses in the transformers, motors, and cables should be minimized.

   a. Transformers

   As per E.C.B.Code transformers with losses not exceeding as below be used.

Power Transformer Losses (ECBC- Table 8.1 & 8.2) For 11 KV Class

Rating KVA	Total Losses at 50% Loading [KW]		Total Losses at rated Load [KW]	
	Oil Type	Dry-type	Oil Type	Dry-type
100	0.52	0.94	1.80	2.40
200	0.77	1.29	2.20	3.30
200	0.89	1.50	2.70	3.80
250	1.05	1.70	3.32	4.32
315	1.45	2.00	3.63	5.04
400	1.52	2.83	4.63	6.04
500	1.60	2.80	5.50	7.25
630	2.00	3.34	6.64	8.82
1000	3.00	4.50	9.80	12.00
1250	3.60	5.19	12.00	13.87
1600	4.50	6.32	15.00	16.80
2000	5.40	7.50	18.40	20.00
2500	6.50	9.25	22.50	24.75

- Oil type should be preferred over Dry type as these are 50-60% more efficient at 50% loading and 10-15% more efficient at Full Load.
- Normal loading being 50-60%, except for peak hours, unless otherwise required due to fire safety norms and I.E. Rules (in situations like installations in basement or below occupied building) oil type transformers should be invariably installed.
- For losses in 22KV & 33KV Class please refer ECBC 2007

b. Minimize losses due to Power factor, Harmonics and Transmission of Power -
   - Power Factor Correction: All sub-stations shall maintain power factor between 0.95 lag and unity.
   - Total Harmonic Distortion (THD): in all equipment should be kept lower than 10%.
   - Power Distribution Losses: Power cabling shall be adequately sized to keep distribution losses below 1% of total power usage.
   - Electrical Metering & Monitoring: Metering should be provided for monitoring & control of Quantity (KVA, KWH, Phase current & Voltage, PF) & Quality (THD) at all Floor Panels and major power consumption centers, like AC Plants, Central UPS, Severs, Ventilation Panels, etc.

c. Energy Efficient Motors:
   - While selecting motors, motor HP Rating should not exceed 20% of the calculated maximum load being served.
   - Always select EFF1 motors for continuous duty equipment such as Pumps, AC plant, Normal Air Supply blower in ventilation, STPs, FF Jockey Pumps, etc.
   - EFF2 motors should be used only in case of very infrequently operation equipment such as Smoke Extraction Blowers, FF Main Pumps, etc.
   - After rewinding, a new efficiency test shall be performed and efficiency record should be maintained.

Performance characteristics of 4 Pole Energy Efficient Induction Motors : ECBC Table 8.4

Rated Output		Full Load Current Max (Amp)	Initial Current in terms of Full running Current		Nominal Efficiency (%)	
KW	HP		For eff 2	For eff 1	For eff 2	For eff 1
0.37	0.5	1.4	5.5	6	66	73
0.55	0.7	1.7	5.5	6	70	78
0.75	1.0	2.2	5.5	6	73	82.5
1.1	1.5	2.9	5.5	6	76.2	83.8
1.5	2.0	3.8	5.5	6	78.5	85
2.2	3.0	5.1	6	7	81	86.4
3.7	5.0	8.1	6	7	84	88.3
5.5	7.5	11.4	6	7	85.7	89.2
7.5	10.0	15.4	6	7	87	90.1
9.3	12.5	18.5	6	7	87.7	90.5
11	15.0	22	6	7	88.4	91
15	20.0	30	6	7	89.4	91.8
18.5	25.0	36	6	7	90	92.2
22	30.0	43	6	7	90.5	92.6
30	40.0	56	6	7	91.4	93.2
45	60.0	84	6	7	92.5	93.9
75	100.0	134	6	7	93.6	94.7

For Motor HP not given above, please refer ECBC 2007
EFF1 is a high efficiency motor. EFF2 is a standard efficiency motor.

2. **Lighting:** After Air-conditioning, lighting is major consumer of energy. Efficient use of lighting can be achieved by-
   - Lighting control: Manual & Automatic "On-Off" Control for indoor lighting should be provided.
   - Occupancy sensors for all area should be provided.
   - Day Light sensors to be provided in area having day light ingress with Automatic "On-Off" Control. Funds available may allow use of dimming controls also. All supplemental task lighting in space shall have a separate control.
   - High PF(>0.9) CFL should be used.
   - T-5 with electronic ballast (<10% THD) should be preferred for direct indoor lighting.
   - Power consumed by Internally Illuminated Exit Signs shall not exceed 5 W per face.

   ECBC provides for maximum Light Power Density as follows-

Interior Lighting power -Space Function Method (ECBC table 7.2)

Space Function	LPD (W/m^2)
Office	11.8
Conference / Meeting Hall	14
Class Room / Lecture / Training	15.1
Audience seating Area:-	
Gymnasium	4.3
Convention Centre	7.5
Sports Arena	4.3
Dining Area :-	
Hotel	14
Bar Lounge / Leisure	15.1
Family Dining	22.6
Food Preparation	12.9
Museum	8.6
Banks office-Banking activity area	16.1
Parking Garage Area	2.2

Exterior Lighting Building power (ECBC table 7.3)

Exterior Lighting Applications	Power Limits
Building Entrance (with canopy)	13 W / m^2 of canopied area
Building Entrance (without canopy)	90 W / linear metre of door width
Building Exit	60 W / linear metre of door width
Building Facade	2 W / m^2 of vertical facade area

For areas/ applications not shown here please refer ECBC 2007.

3. **Service Water Heating & Pumping:** Solar Water Heating is a major contributor towards energy saving. The Geysers/ Storage Type Electric Water Heaters, where unavoidable, should be selected with losses not exceeding as given in ECBC. The insulation of the Hot Water Pipe, should as given below.
   a. Solar Water Heating system:
      - Residential facilities, hotels and hospitals to have solar water heating system for at least 1/5 of design capacity.
      - Thermal efficiency of water heaters under test condition to be 80% or more.

   b. Standing loss in Storage Type Electric Water Heaters (ECBC- Table 6.1)

Rated Capacity in Ltrs	Loss in KWH / day for 45° temp. Diff.
6	0.792
10	0.99
15	1.138
25	1.386
35	1.584
50	1.832
70	2.079
100	2.376
140	2.673
200	2.970

   c. Insulation of Hot Water Piping (ECBC- Table 5.6)

Designed operating temperature of piping	Insulation with Min. R-Value (m^2-K/W)
60°C and above	0.74
Above 40°C and below 60°C	0.35

4. **Heating , Ventilation & Air Conditioning**
   - Air-Conditioning consumes 60% of the energy used in the building. Efficient Air-Conditioners, hence, are a must.
   - Select the most efficient WTAC and Split type AC from the BEE Star Rating.
   - For the Central Plants, the COP and the IPLV should be the selection criterion.
   - Appropriate insulation of the Chilled and Hot Water Pipes, Ducting goes a long way in saving losses in Air-Conditioning. The details of R values recommended are given below.

a. Minimum Equipment Efficiencies:

i) Direct Expansion (DX) System:

Unitary Air Conditioners (WTAC) -

Power Consumption rating Under test Conditions (ECBC- Table 5.3)		Maximum Power Consumption for a 5 Star Rated WTAC as per BEE for Jan,2012 to Dec., 2013
Kcal/H	Consumption (KW)	Consumption (KW)
1500 (0.50 TR)	1.10	Not Given, EER 3.3
2250 (0.75 TR)	1.40	Not Given, EER 3.3
3000 (1.00 TR)	1.60	0.99
3750 (1.25 TR)	2.00	Not Given, EER 3.3
4500 (1.50 TR)	2.40	1.575
6000 (2.00 TR)	3.20	Not Given, EER 3.3
7500 (2.50 TR)	4.25	Not Given, EER 3.3
9000 (3.00 TR)	5.20	Not Given, EER 3.3

Spilt Air Conditioners -

Power Consumption rating Under test Conditions (ECBC- Table 5.4)		Maximum Power Consumption for a 5 Star Rated WTAC as per BEE for Jan,2012 to Dec., 2013
Kcal/H	Consumption (KW)	Consumption (KW)
3000 (1.00 TR)	1.70	1.04
4500 (1.50 TR)	2.60	1.59
6000 (2.00 TR)	3.40	1.895
7500 (2.50 TR)	4.50	Not Given, EER 3.3
9000 (3.00 TR)	5.40	Not Given, EER 3.3

For details please refer the BEE web site.
The EER is being targeted by BEE to be upto 3.5 for the period Jan.,2014 to Dec., 2015 for 5 Star rated units.

Packaged Air Conditioners -

Power Consumption rating Under test Conditions (ECBC- Table 5.5)		
TR	Consumption (KW) (**Water Cooled**)	Consumption (KW) (**Air Cooled**)
5	6	7
7.5	9	10
10	11.5	13.5
15	17	20

ii) Central Plants:

Chillers (ECBC- Table 5.1)		
Water Cooled Chillers, Compressor Type - Rotary Screw/ scroll	**Minimum COP**	**Minimum IPLV**
<530KW (<150 TR)	4.7	5.49
≥530KW &<1050KW (≥150TR & <300 TR)	5.4	6.17
>1050 KW (>300 TR)	5.75	6.43
Water Cooled Chillers, Compressor Type - Centrifugal	**Minimum COP**	**Minimum IPLV**
<530KW (<150 TR)	5.8	6.09
≥530KW &<1050KW (≥150TR & <300 TR)	5.8	6.17
>1050 KW (>300 TR)	6.30	6.61
Water Cooled Chillers, Compressor Type - Reciprocating	**Minimum COP**	**Minimum IPLV**
All Sizes	4.20	5.05
Air Cooled Chillers	**Minimum COP**	**Minimum IPLV**
<530KW (<150 TR)	2.9	3.16
≥530KW (≥150TR)	3.05	3.32

iii) Controls:

a) All Cooling systems >8TR and Heating systems >2TR, to be controlled by time clock designed to start & stop system under 3 different day-types.

b) All mechanical cooling & heating systems shall be Temperature controlled by Thermostat.

c) All Cooling towers and closed circuit fluid coolers shall have either two speed motors or variable speed drives for controlling fans & pumps.

iv) Insulation for Piping & Duct Work:

Hot Water Piping -

Designed operating temperature of piping	minimum R-Value (m^2-K/W)
60°C and above	0.74
Above 40°C and below 60°C	0.35

Chilled Water Piping -

Designed operating temperature of piping	minimum R-Value (m^2-K/W)
Below 15°C	0.35

Duct work -

Duct Location	Required Insulation R-Value (m^2-K/W)	
	Supply Ducts	Return Ducts
Exterior	R-1.4	R-0.6
Ventilated Attic	R-1.4	R-0.6
Unventilated Attic without roof insulation	R-1.4	R-0.6
Unventilated Attic with roof insulation	R-0.6	No requirement
Unconditioned Space	R-0.6	No requirement
Buried	R-0.6	No requirement

v) Pumps -

a) Primary Pumps without VFD.

b) Secondary Pumps with motor >3.7KW(5HP) to be with VFD to reduce the flow rate to 50% of design value.

5. Solar Power Generation -

As in Solar Heating, Solar Power Generation also reduces the demand of energy from conventional sources. With improvement in technology, SPV modules are available with improved efficiency and elimination of mandatory use of batteries by use of Grid Interactive System has helped in reduction of atmospheric pollution by lead and acids. While selecting the system following points are to be considered:

- Efficiency of SPV Panel to be 16% and above.
- Presently efficiency is available up to 21%, but is very costly.
- Use On-line Grid Interactive, SPV Generation system to save on Battery cost & losses on charging of battery, besides pollution control.
- Prefer Power Conditioning Units with Maximum Power Point Tracking (MPPT) based inverters as efficiency is of the order of 96%.
- Normal requirement of space is 12sqm per KWp of Solar Power Installation.
- Utilize maximum roof space available for SPV & SWH.
- Building Integrated Photo Voltaic (BIPV) meeting Roof Assembly & Vertical Fenestration can be used for further augmentation of SPV generation.

Part-IV

Guidelines on Reuse & Recycling of Construction & Demolition Waste

1 Background

With the development of society at all the fronts, lots of construction activities are seen everywhere. Mega construction activities are going on everywhere, rather increasing exponentially. Also, the demolition of existing structures, which have outlived its service life, is going on simultaneously. It is not essential that the structures need to be demolished only after their service life span is over, but also due to ongoing trend of reconstruction of even healthy structures just for creating more space in order to meet the present requirement. All such activities are generating huge amount of waste, called the Construction and Demolition waste. Disposal of such debris in a safe environment is a big challenge for the builders, developers and owners.

On one hand the disposal of debris is a challenge, on the other hand there is an acute shortage of naturally available aggregates for construction of buildings. Reduction of this demand is possible only with the reusing or recycling of construction and demolition waste generated from the construction activities. Hence, the construction sector must accept the use of C& D waste wherever feasible. This will lead to a significant saving in virgin raw material and consequent reduction in waste disposal.

2 Promotion of C&D Waste Management

Since the concept of C& D waste management is new, it is essentially required to spread the education and information in order to gain the public support. It is required to sensitise not only the Engineers, but all stockholders including regulatory authorities in construction industry. Establishment of effective strategies and enactment of laws and regulations is essential to achieve this.

3 Reusing And Recycling of C&D Waste

3.1 Reusing of Construction and Demolition waste

Reusing of construction and Demolition waste is different from Recycling. It does not require any further processing to convert into a useful product. The items which are usable directly are screened out from the debris and put into the intended use without further processing or the application of any further energy for conversion into the useful product. Thus reusing a waste item is a better service to the environment and the environment is saved from further impacts due to recycling activities. For example, full bricks can be screened out of the demolition debris and used as it is for building a partition wall. Otherwise same would have been converted into smaller pieces for using it as an aggregate or brick bats for plinth protection etc.

Since the reusing of C&D waste is always more advantageous, it is essential that to have more and more reusable materials in debris. This is possible, if sufficient precautions are taken while a building is demolished. There should be an effective deconstruction plan instead of just converting the standing structure into debris within minutes. Useful products like doors and windows, bricks, reinforcement, from RCC components, structural steel can be taken out with little extra efforts and put into reuse without much processing.

3.2 Recycling of Construction and Demolition waste

Once the waste generated from Construction and demolition waste has been segregated and reusable items are taken out, the leftover waste is now available for recycling. Recycling of this waste into useful products to extend the service to environment is a challenge.

4 Reusing And Recycling Potential of Different Materials

The amount of C&D wastes in India has been estimated to be 10 - 12 million tonnes annually and the proportion of concrete estimated as 23 to 35% of total waste. Considering 30 % percent of C&D wastes of 12 million tonnes as concrete, and 50 % of the concrete as coarse aggregate, the total available recycled concrete aggregate (RCA) in India is of the order of 1.8 million tonnes annually

4.1 Concrete

Concrete is primarily a composition of cement, coarse aggregates, fine aggregates and water, further processed by addition of industrial products/ by products for enhancing the strength. Engineers are mainly dependent on nature for obtaining the Coarse and Fine aggregates as well as water for the chemical reaction with cement. Scarcity is there for all these naturally occurring materials and need is there to explore alternative sources. Even for the water with required properties, shift is towards the use of waste water after due treatment. One of the alternative sources of coarse aggregates is recycled concrete aggregates (RCA) which are obtained from the processed Construction and Demolition (C&D) waste. During and after the demolition of any concrete structure, the demolished concrete waste is taken to a recycling plant and there crushed into the required sizes which is called the Recycled concrete aggregate (RCA).

Sometimes, good sized precast element are also obtained during the demolition, which have a potential of being reused or otherwise, these are also crushed and converted into the recycled aggregates. Limitation is there in use of these recycled aggregates. The production of concrete in India is governed by BIS and IRC codes i.e. IS: 456, IS: 1343 or IRC: 112. All these codes allow the use of naturally occurring aggregates only conforming to IS: 383. To overcome these limitations, it is required to make a special provision of use of Recycled aggregates in combination with naturally occurring aggregates. Thus, use of recycled aggregates can be there with different value of their share by suitable replacing the component of naturally occurring aggregates. It will help out not only in meeting the situation where there is acute shortage of natural resources, but also a step towards the sustainability.

4.2 Bricks

Bricks are the important building material in the construction of residential as well as non -residential buildings. It is also a significant component of the total C&D waste on new residential construction sites. Bricks are largely treated as waste when broken or damaged from the brick production line or from construction site due to poor internal handling and excessive cutting. Brick is a maintenance-free component of the structure which is durable during the complete service life of the building. The high durability property of the brick makes it environmental friendly in the sense that after the demolition of the structure, it can be reused repeatedly and the left over volume which is non-reusable can be recycled for other beneficial purposes. During the demolition process itself, bricks obtained are stacked for next use in its original form after the removal of mortar which is chiseled out and make the brick ready for reuse or recycling, if not reusable.

Bricks, after the removal of the stuck up mortar remain reusable for restoration or for new homes and projects. Recovered bricks can be used like a fresh lot of bricks without any further processing. These can also be laid on as brick pavers or for landscaping or any other artistic creations. Brick paved streets are aesthetically pleasing and rain water also percolates through the pavement. Also, a brick surface is cooler in hot months. These street advantages make bricks a good choice in driveways. Bricks on edge are also sometimes used as economical pavement solutions in smaller compounds.

Construction debris consisting of bricks can be recycled into brick aggregate through screening, crushing, re-screening and blending, which can then be used as pavement base material by proper mix proportions with cement and fly ash. Brick waste which are not suitable for recycling into the pavement base materials can be used in construction/land fill. Concrete prepared from crushed brick aggregate has good engineering and also better thermal properties but has greater shrinkage than ordinary concrete. Sometimes, during the manufacturing of bricks, due inadequate burning, or sometimes due to over burning, whole lot is turned into the production waste. Though this waste is different from construction and demolition waste, but it can also be recycled like C& D waste and can be suitable used for production of precast elements like paver blocks, kerb stones, interlocking tiles by mixing with cement and using as a concrete mix.

4.3 Tiles

Generally, it is difficult to extract tiles from the walls in proper shape and size in order to find them suitable for reuse. It also depends upon the type of the tiles, their life span and the existing conditions. Seepage behind the walls due to leaking water pipes makes them totally non usable. Still tiles extracted from walls, even if these are broken pieces, provide an excellent opportunity to the artists /designers for making murals or other decorative master pieces. Broken tiles can also be used aggregate after crushing.

If the tiles can be extracted or removed from the wall in good shape and size, these are reused for the same purpose after the removal stuck up mortar and then glued with suitable adhesives available in market today. Creative items like artifacts, table tops, special effects in drive ways, pedestrian subways etc. can be smartly created by reusing for a wide variety of projects.

The broken tiles can be further crushed into smaller sizes and can be a partial replacement of gravel and crushed stone in making concrete.

4.4 Timber

The waste timber is not only produced from the demolition of the building, but also from construction of wooden building wherein lot of timber waste is generated. Each source has its own system of recycling and reuse of recovered timber from the demolition of a building or the construction of a building. Whenever a building is decided to be dismantled, timber products like doors and windows are the items which are removed as first step and that too in original form. Timber products have a quality of a long service life which is much longer than the life of the building itself. Hence, in general such products unless eaten by the termites or damaged due to fire do not lose the Engineering properties for a long time and can be used multiple times and thus an environmentally friendly product.

The waste timber which has not been recovered in its original form or non-usable in same shape and size can be recycled into new particleboard, medium density fibre boards, animal bedding or used to make renewable energy. Timber used for recycling has to be free from any other demolition products like concrete, mortar, aggregates, sand, bricks, plastic, metals, tiles etc. Wood chips are produced from good quality wooden waste such as large size lumbers. Some of the particleboard producing companies and the pulp and paper producing companies are still using the recycled chip for their products.

4.5 Metals

Amongst the metals, steel and Aluminium are the two major products obtained as waste during the construction as well during the demolition of a building. Structural steel obtained during the demolition of a steel structure or left over steel during the construction can be reused directly without much processing. The members can be resized as op the requirement and can be reused directly. Aluminium scrap can be put into reuse by the solid bonding process. If a care is taken in initial stages i.e. during designing with a valid deconstruction plan, then the reusable scrap can be increased to a much greater extent like house hold appliances, without taking the routing the scrap through a foundry. Reusing a steel beam its existing form is better than re-melting it and rolling a new steel beam, i.e. the energy used to re-melt the beam is saved.

Steel waste occurs during the construction and refurbishment of buildings and when they are ultimately demolished and the material becomes available for recycling. Waste from the manufacture of steel construction products can be easily collected and segregated for recycling. Steel generates almost nil wastage on the construction site. Waste steel which is reusable is equally good in durability criteria and the quality is also well maintained while making products like fire hydrants, steel furniture and also ecologically sustainable.

As far as Aluminium is concerned, it is recyclable multiple times and is always on demand with the need to preserve the environment. Recycling scrap aluminium requires very less energy in comparison to the energy requirement of new aluminium. Because aluminum is infinitely recyclable, it can be reused in applications vastly different from its previous purpose, and it can also be recast into its original form. These properties make aluminum an ideal material for use in premium applications, even after being recycled many times.

4.6 Plastic

Scrap or waste plastic recovered from demolition or construction site is reprocessed and transformed into the entirely different useful products. When compared to other materials like glass and metals, plastic polymers require greater processing to be recycled. The most-often recycled plastic HDPE (high-density polyethylene) is reduced to plastic lumber, tables, roadside curbs, benches, truck cargo liners, stationery (e.g. rulers) and other durable plastic products and is usually in demand. Other application of recycled plastic is in the preparation of a road surface that includes recycled plastic aggregate, bitumen (asphalt) with plastic that has been shredded and melted at a temperature below 220° C (428 °F) to avoid pollution. Such road surfaces are very durable and monsoon rain resistant.

4.7 Asphalt Concrete

Demolished asphalt concrete can be utilised as aggregates for asphalt concrete. Also, the demolished asphalt concretes can be used for land fill.

4.8 Asbestos

Generally, asbestos is disposed as hazardous waste in landfill sites. The demolition of buildings containing large amounts of asbestos based materials have to be deconstructed piece by piece or the asbestos has to be removed carefully before the structure can be demolished. Workers must wear heavy protective equipment. It is important to ensure that asbestos waste has been wetted and sealed in heavy-duty plastic prior to transportation to an approved landfill.

4.9 Excavated Material

Excavated materials are many times contaminated and require special handling and disposal. It may include hazardous as well as non-hazardous material. Excavated contaminated material that can be re-used will be decontaminated prior to re-use, or if not suitable for re-use will be transported to appropriate treatment facilities or approved landfill sites. If the excavated materials are found suitable for re-use as road fill base material, then the cut and fill quantities will be balanced to avoid any off-site disposal. Excavated soils will be retained on site for re-use as backfill while hard rubble will be crushed and re-used on site. Unsuitable material for engineering fill can be used for landscaping.

5 Simple Guidelines to be Followed in Recycling

The agencies responsible for generation of wastes should separate the generated wastes having potential for reuse/recycling. The Engineer-in-charge will select structure's type and materials that are suitable for reuse/recycling, use recycled aggregates, and ensure proper treatment of wastes generated from such development. The waste generation from construction should not only be minimised, but should also minimise the hazardous effect from the generated wastes.

5.1 Various agencies (or sub-contractors):

Various agencies or sub-contractors to be involved are to be linked up with the steps in this process of C& D waste reuse and recycling. Some of such steps can be listed as waste collection and transportation, waste middle treatment i.e. receiving the waste, its segregation and further suitable comprehensive treatment before putting into the use. The cost for C&D waste separation, storage, treatment, reuse/recycling should be included in the Estimated Cost by the Engineer-in-charge while according Technical sanction and preparing tender documents.

There are important duties to be either assigned or as a dutiful contractor, he may be establishing himself like, he should establish step-by-step demolition plan. Contractor may establish treatment facility at site only. He should report expected amount of wastes by type and treatment plan at the beginning of construction. There should be effective utilization of recycled aggregates and Safe treatment of hazardous waste like asbestos.

Contractor may be asked to submit Environmental Management Plan during Construction.

5.2 C&D waste information on web

All C&D waste information by contractor and by those involved in its treatment waste treatment companies are to be put on public domain in order to improve the rate of use of demolished concrete for e.g. application of recycled aggregates. Further to have a stronger data base of C&D waste, users reusing the C&D waste or recycled waste after treatment and processing can contribute a lot. This will help in substantial reduction on the amount of wastes and promotion of recycling or reusing the C&D waste.

5.3 Demolition Plan

It is required to adopt a systematic approach while demolishing a building in order to minimise the waste and its best use. A recommended approach can be to follow a sequence of segregation of household waste as first step followed by mechanical and electrical equipment, exterior and interior finishing materials, roof finishing and water-proofing materials, then structure as a last resort. Demolished C&D wastes need to be brought out of field immediately or temporarily stored in a designated area for the C&D wastes.