ECO-FRIENDLY BUILDING MATERIALS AND TECHNOLOGIES FOR PUNE – SECTION II

6. FINANCIAL AND ENVIRONMENTAL IMPLICATIONS

To understand the financial implications of implementing the eco-friendly alternatives a cost deviation study was conducted. Due to the wide range of prices of building materials, the cost deviation was found to vary within the alternatives recommended based on the type of material selected. Certain materials although costlier than the conventional/base material can provide cost saving based on its usage and application. These cost deviations along with the environmental benefits have been discussed below in the order of recommendations in the above chapter.

6.1 COST DEVIATION AND USAGE ANALYSIS

6.1.1 Structural System

Base Material for R.C.C. and Steel Systems

1.(a) **Pozzolana Material content** (Fly ash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (fly ash and calcined clay based) and IS455 (slag based) and / or direct addition of pozzolana material (fly ash as per IS3812, Slag as per IS3812 and Calcined Clay as per IS12089). A minimum of 25% content of the pozzolana material is mandatory and the builder, beyond the use of a BPC, can further increase the content level by directly adding raw pozzolana material brought from its production source such as thermal power plants, blast furnaces etc. The usage of fly ash increases the strength of concrete from 25-50%, makes the concrete more workable and increases the water resistance of the finished surface. Amount of water required for curing concrete containing fly ash is much lower as compared to ordinary Portland cement (OPC) concrete. There is a considerable decrease in the costs, as fly ash / BPC is cheaper, concrete is more compact, water resistance of finished surface is enhanced and curing water consumption is lowered. The use of fly ash reduces the overall cost by about 10-20%.

2. (a) Refer to note 6.1.1- 1.(a)

2. (b) **Sand and aggregates** obtained from sintered fly ash and pulverized construction / demolition debris are an excellent alternative for their naturally obtained counterparts due to their similar physical and chemical properties. It is best to produce sintered fly ash near the source of fly ash production whereas pulverization of debris should be done on site. It is advisable to start initial construction activities such as construction of site office, site toilets and other similar pre-construction activities with the available debris. These alternatives cost about 20-40% lesser than their conventional counterparts owing to the elimination of natural resource usage and reduced transportation costs.

2. (c) **Steel** from electric arc furnaces can run on 100% scrap inputs and the conventional blast furnaces can take about 30% scrap input. It is possible to reduce the embodied energy for steel by about 75% through the recycle and reuse process. The market prices for steel made from virgin resources and that made from recycled scrap is the same, hence there is no significant cost deviation.

Alternative Systems

3. (a) Components made of **Ferro cement** instead of the conventional reinforced cement concrete (RCC) cost almost 20-30% lesser. The cost of a ferro cement based component is highly design specific and thus cannot be easily compared by means of a costing thumb rule. The technology being highly adaptive and versatile has a limitless potential of usage. A entire structure can be constructed from ferro-cement if designed specifically for it. Ferro cement being lightweight reduces the dead load on the structure considerably thus indirectly reducing the structural costs. Ferro cement requires minimal or no shuttering / formwork and lesser quantity of water for curing thus further reducing the cost. As ferro cement uses less of steel and no aggregate, virgin resource usage is minimized.

Pre-cast reinforced cement concrete units perform at par with the ferro cement components with approximately 30-40% cost reductions. The added advantage with pre-cast technology is that the manufacturing process can be streamlined and product quality can be assured. Mass production of pre-cast components results in lesser material wastages, consistency in quality and minimal usage of water for curing. Pre-cast RCC is the same as conventional RCC, the only difference being that the pre-cast elements are made off-site unlike the later on site method. On site casting of RCC elements have limitations on formwork and curing methods that are eliminated by the use of casting moulds and curing water tanks in the case of pre-cast RCC. For example, a regular RCC slab of 125mm thickness should actually be only 65mm thick to cater to the load above. Since on site formwork limitations do not permit such thin sections one has to cast a minimum 125mm thick slab. A 50% reduction in the cross section area means a similar reduction in the material consumption and dead load on the structural system. Moreover, pre-cast elements can be used efficiently for most of the building components.

3. (b) **Ready Mix Concrete** (RMC) delivery system has increased the efficiency levels throughout the construction project. Larger volumes can be cast at higher speeds with a consistent concrete composition. Since concrete mixing plants are located off site, the need for storage and maintenance and wastage of raw materials like cement, sand and aggregate on site is minimized considerably. RMC is cheaper by approximately 30-50% than on site mixed concrete owing to the bulk handling and usage of base materials and reduced storage and labour requirements. The above-mentioned set of advantages render this delivery system superior to the conventional one. In case of ferro cement construction, one cannot use the RMC process, since concrete is used in small quantities and needs to be freshly mixed to suit the requirements and the purpose.

3. (c) **Curing agents** for concrete can be made use of, to minimize the use of water while curing. These agents can either be in the form of chemical admixtures or surface coat type. The admixture-type curing agent helps in slowing down the rate at which the heat of hydration is released, thus reducing the frequency for curing. The surface application type is a resinous viscous fluid applied to the concrete surface after the initial setting of concrete is done. Initial curing for concrete is required and once the surface curing coat is applied, no more water curing is needed. This method is highly efficient for vertical surfaces where water is not retained easily while curing. These curing agents are relatively expensive, thus resulting in a high cost deviation of about 200-300% from the conventional method.

6.1.2 Masonry

1. (a) Conventional masonry units such as bricks and cement concrete blocks can be replaced by a set of more eco-friendly units. The cost of these new bricks and blocks vary over a range much higher than the conventional bricks used today. But there is an indirect cost reductions resulting from the use of such eco-friendly units. Compared to bricks, the alternative units have better dimensional finish with low / no surface level deviations. Thus the thickness of plaster that needs to be applied on their surfaces is comparatively more consistent over the entire wall, thus reducing the amount of plaster and mortar needed. Moreover, units such as the fly ash-sand-lime based and the pulverized debris based give a good finish themselves with no further need for plastering. These can also be used when exposed masonry is desired and can sustain a taller load bearing structure owing to their greater compressive strengths. Pigments can also be easily mixed to achieve variations in their colours. Most of the alternatives are derived from a range of industrial and agro waste products. A comparative cost analysis for some of these alternative units is as shown below.

Table 6.1 - Cost Comparison for Masonry Units

Material	Cost* (Rs./Cu.Mt.)	Cost Deviation (%)		
		75%brick + 25% Alt.	50%brick + 50% Alt.	25%brick + 75% Alt.
Fired Clay Brick	1007	Base	Base	Base
Fly Ash+Sand+lime	1851	+ 21	+ 42	+ 63
Pulverized Debris based	1300	+ 7	+ 15	+ 21
Industrial Waste based	1851	+ 21	+ 42	+ 63
Cement Concrete Blocks	3462	+ 61	+ 122	+ 183
Aerated Lightweight CC Block	3462	+ 61	+ 122	+ 183

6.1.3 Mortar

1. (a) **Pozzolana Material content** (Fly ash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (fly ash and calcined clay based) and IS455 (slag based) and / or direct addition of pozzolana material (fly ash as per IS3812, Slag as per IS3812 and Calcined Clay as per IS12089). A minimum of 25% content of the pozzolana material is mandatory and the builder, beyond the use of a BPC, can further increase the content level by directly adding raw pozzolana material brought from its production source such as thermal power plants, blast furnaces etc. The usage of fly ash increases the strength of mortar from 25-50%, makes the mix more workable and increases the water resistance of the finished surface. Amount of water required for curing concrete containing fly ash is much lower as compared to ordinary portland cement (OPC) concrete. There is a considerable decrease in the costs, as fly ash / BPC is cheaper, mortar mix is more compact, water resistance of finished surface is enhanced and curing water consumption is lowered. The use of fly ash reduces the overall cost by about 10-20%.

2. (a) Refer to note 6.1.1 – 2. (b)

2. (b) Refer to note 6.1.3. – 1. (a)

6.1.4 Plastering

1. (a) **Calcium Silicate based plaster and plasterboards** have similar physical properties as compared to gypsum plaster or plaster of Paris. Calcium silicate boards cost almost 25-50% more than gypsum plaster or plasterboards. In comparison with the conventional gypsum based products, calcium silicate based ones are stronger, have more moisture resistance and can be made termite and vermin resistant. Their superior performance and behaviour makes them more versatile, rendering them useful in a larger number of places. The finished surface is stronger and less porous, has no leaching and efflorescent characteristics and a high level of dimensional stability. Fixing of calcium silicate boards is much easier owing to its strength – can be fixed by hammering a nail or drilling screws, unlike in the case of gypsum or Plaster of Paris which tend to chip off easily. This material is also an insulating agent to an appreciable level. Hence, even though being costlier, calcium silicate based products out perform their conventional counterparts, thus reducing it life cycle costs.

1. (b) **Cement plaster**, the most widely used plastering material is recommended here only if its component materials comply with the recommendations in point 6.1.1. – 2.a. Mainly the sand used in the mix shall be in accordance with the IS1542 standard. Sand used, may be artificially generated, such as sintered fly ash and / or pulverized construction / demolition debris. Using artificial sand reduces the environmental impact much created due to sand dredging and stone quarrying.

The cement used, must comply with point 6.1.1 – 1. (a) in this sheet, which specifies that a minimum 25% pozzolana content must be attained in the blended Portland cement used. By incorporating these alterations, the cost reduces by about 10-25%.

1. (c) **Fiber reinforced clay plaster/ Phospho-Gypsum Plaster/ Non-erodable Mud Plaster** - These are innovative technologies developed by organizations such as Building Materials & Technology Promotion Council (BMTPC) and Central Building Research Institute (CBRI). These techniques have been used in various public projects undertaken by these organizations but have to yet establish itself in the building industry and the associated markets. The techniques and processes use environmentally friendly materials, industrial and agro waste materials and recycled materials and are cheaper as compared to their conventional counterparts. However, these materials tend to have a lesser life and could have finishing limitations and dimensional instability. But these disadvantages are easily over shadowed by the eco-performance of each of these alternatives, thus making them a much more preferred choice. These techniques also have a higher and more versatile aesthetic value.

1. (d) Refer to note - 6.1.1.- 3. (c)

6.1.5 Roofing and Ceiling

1. (a) **Fiber Reinforced Polymer** (FRP) Plastics are an excellent alternative to other plastics such as PVC, Acrylic and Polycarbonates. Not only is FRP more energy efficient while manufacturing, but it also has a better life cycle performance compared to the other plastics. The material is more versatile and mouldable, hence rendering it useful in more number of places. Its ability to contain colour pigments imparts a higher aesthetic value. A much stronger material, FRP can be used as external cladding, roofing, flooring etc. The most widely used type is the glass fibre reinforced plastic that makes use of recycled glass. More number of fiber variations have been incorporated owing to constant research and innovation. Polymers can also be reinforced using recycled plastics and sometimes also agro fibre wastes. Usage of the alternatives recommended could increase the cost by about 10-50%, but on the other hand a longer life and better performance can be assured.

Table 6.2 - Cost Comparison of Roofing Materials

Material	Cost (Rs./Sq.Ft.)	Cost Deviation (%)
PVC, Plain sheet	45	Base
Foam PVC, 10mm thick	90	+ 100
Polycarbonate sheet	70	+ 55
Acrylic	40	- 12
FRP	60	+ 33

1. (b) **Micro Concrete Roofing** (MCR) Tiles and Bamboo Matt Corrugated Roofing (BMCR) Sheets are an efficient, eco-friendly alternative to conventional products such as corrugated aluminium and asbestos sheets and Mangalore tiles. The overall cost involved in these alternative systems is approximately the same as that for mangalore tiles or any corrugated sheets. MCR tiles have the added advantage of being lightweight, more durable and heat resistant and can be coloured as per users preference. Being cement based, MCR tiles can be made using BPC and fly ash making them more eco-friendly. BMCR sheets have a high load carrying capacity and have a lesser thermal conductivity than its conventional counterparts. Both these alternatives being weather proof and having a higher aesthetic value as compared to the conventional products make them a better choice. Depending upon their usage extends and the materials they replace, we observe a vast range of values over which the cost deviates. To best understand and compare the costs of some of the conventional materials with the suggested alternatives, one must compare the values mentioned in the table below.

Table 6.3 - Cost Comparison for Roofing Alternatives

Material	Cost (Rs./Sq.Ft.)	Cost Deviation (%)	
		50%G.I. + 50% Alt.	25%G.I. + 75% Alt.
Galvanised Iron Corrugated sheets on steel support	40	Base	Base
Asbestos Cement Corrugated Sheets on steel supports	37	- 4	- 6
Aluminium Corrugated sheets on steel supports	53	+ 16	+ 24
Mangalore Tiles on Primary Wood supports	48	+ 10	+ 15
PVC Corrugated sheet on steel support	42	+ 2	+ 3
MCR Tile on steel support	33	- 9	- 13
MCR Tile on Primary Wood support	36	- 5	- 8
Bamboo Matt Corrugated Sheet on Primary Wood support	45	+ 6	+ 9

6.1.6 Flooring, Paving and Road Work

1. (a) Paving blocks are recommended for external hard surfaces since they permit percolation of water down to the soil below. A better alternative to making tarred surfaces, the blocks have a high durability, can be colored as per users choice and also can be replaced / repaired with much ease. With costs for the paving blocks varying between 20-25 Rs./Sq.Ft., it is a much cheaper option than making tar roads. Moreover, these blocks should be made using waste material such as fly ash, industrial waste and pulverized construction / demolition debris with a suitable BPC.

1. (b) Bedding sand used for pavements and blocks gives a uniform surface to lay the blocks / units upon. It is important to have a water permeable layer to allow the rainwater to percolate through to the soil. Sand dredging and stone quarrying is a huge contributor to the growing eco-hazard in our country. In an effort to minimize the use of such natural river sand and crushed stone sand, the recommended alternative specifies the use of sand made through pulverization of construction / demolition debris. This debris has similar properties as that of natural sand or crushed stone and hence suits the purpose. This pulverized debris sand replacement would cost about 40-50% lesser compared to its natural counterparts.

1. (c) Terrazzo flooring is an eco-friendly alternative made using waste and recycled material. Primarily made using chips of broken tiles, stones and various other ceramic articles. Cement and epoxy resins are the most widely used binders for such type of flooring. Since this type of flooring can be laid out seamlessly, it helps form a good waterproofing layer on exposed surfaces such as terraces and balconies. Moreover, variations in its component materials by adding polystyrene beads can increase its insulating properties. With costs ranging from 20-30 Rs./Sq.Ft., this is a cheap alternative.

1. (d) With the growing demand for vitrified ceramics and natural stones such as granite and marble, consumption of natural resources and energy is rising at an alarming rate. Vitrified ceramic tiles consume a huge amount of energy during the manufacturing process compared to the non-vitrified ones and cost between 3-10 times more. Mosaic and terrazzo flooring tiles have similar costs compared to the non-vitrified ceramics and also have a high aesthetic value and can be altered as per the users choice. Cement tiles with stone dust (marble or granite) have an excellent finish, sometimes comparable to natural marble or granite finish. Innovative materials such as phospho-gypsum based tiles and bamboo board flooring are yet to be commercially available to support the demand in the market. Phospho-gypsum is a byproduct gypsum produced in fertilizer and chemical industries, whereas bamboo is the fastest growing renewable alternative to wood. With durability and performance comparable to their conventional counterparts, these recommended alternatives are easy to adopt. The most commonly used flooring materials are listed below with their costs and comparisons

Table 6.4 - Cost Comparison for Flooring Materials

Material	Cost Rs./Sq.Ft.	Cost Deviation (%)	
		50% Vitrified + 50% Alt.	25% Vitrified + 75% Alt.
Vitrified Ceramic Tile	75	Base	Base
Marble Flooring	125	+ 33	+ 50
Granite Flooring	125	+ 33	+ 50
Kota Stone, 30mm thick - machine cut - one side polish	35	- 27	- 40
Vinyl Flooring	60	- 10	- 15
Bamboo Board Flooring	150	+ 50	+ 75
Terrazzo Flooring	29	- 31	- 46
Marble Mosaic Tiles	20	- 37	- 55
White Glazed Tiles (dado)	15	- 40	- 60
Ceramic (non-vitrified) Tiles	30	- 30	- 45
Plain Cement Tiles	13	- 41	- 62

6.1. 7 Windows, Doors and Openings

1. (a) Refer to 6.1.1. – 3. (a)

1. (b) **Jali work** can be alternatively done using simple masonry bonds such as the rat-trap bond. This particular bond has many advantages over the conventional techniques. Area such as duct and niches can be covered up using this technique. A high aesthetic value and simplicity of workmanship makes this alternative a preferred choice. Walls and partitions made using this type of bond can also serve as insulating members owing to the cavity formed within. This cavity can be filled with the in-fill type insulation. Being a simple modification of a wall construction, the cost incurred is the same as that of walling units. Moreover, cost of lintels, opening frames and precast or fabricated jails is completely eliminated.

2. (a) New innovations and technologies such as frameless doors and bamboo reinforced concrete components help reduce the material usage, dead loads and labour requirements, thus indirectly reducing a considerable amount of the costs. Replacing steel reinforcement by bamboo itself reduces the embodied energy of the product, and increases the use of renewable resources giving us a cheap eco-friendly technology without any compromise on durability, finishing quality and performance.

For Ferrocement & Precast units refer to 6.1.1. – 3. (a)

2. (b) Steel from electric arc furnaces can run on 100% scrap inputs and the conventional blast furnaces can take about 30% scrap input. It is possible to reduce the embodied energy for steel by about 75% through the recycle and reuse process. Similarly aluminium can be recycled and reused. Unlike steel, 100% of aluminium can be recycled hence reducing the embodied energy of recycled aluminium by almost 90-95% than that of virgin aluminium. The market prices for steel and aluminium made from virgin resources and that made from recycled scrap is the same, hence there is no significant cost deviation.

3. (a) **Timber** can be procured from many sources – rain forests, plantations etc. Timber, if used for the purpose of making shutters, shall be from plant species having life cycles ranging between 3-10 years. Usually all plantations are government certified, but one must take added efforts to verify the validity of such certification. Species such as Eucalyptus, Poplar, Kadam and Rubber are fast growing and hence are most suitable for producing plantation timber. Hard wood plantations certified by the government must be avoided on grounds of renewal of such species. Most hard wood species have an average renewal cycle of more than 100 years. Another source of timber is salvaged wood. Demolition sites, old furniture and wood articles, old timber construction etc. are a good source of salvaged wood. Care must be taken to ensure the fitness of such salvaged wood prior to their usage. Sometimes, such reuse might involve vermin treatment using hazardous chemicals; hence the proper use and disposal of salvaged wood must be done. The table below shows indicative costs of some of the species of timber used in the construction industry.

Table 6.5 - Cost Comparison of Timber Species

Material	Cost Rs./Cu.Ft.	Cost Deviation (%)
Burma Teak	1800	Base
Rose Wood	3500	+ 94
Cedar Pine Wood	850	- 53
Silver Oak Wood	280	- 84
Deodar	450	- 75
Sal Wood	550	- 69
Eucalyptus Wood	750	- 58
Rubber Wood	450	- 75

4. (a) Refer to note 6.1.10. - 2 (a)

4. (b) Refer to note 6.1. 10. - 2 (b)

4. (c) **Shutters** used in wet areas need to be water resistant; hence the choice of material must be made carefully. Plastics such as FRP, PVC and polycarbonates are a preferred choice as compared to woods or boards laminated with water proofing elements. Non-corrosive metals such as aluminium are also good options, but one must ensure the usage of recycled aluminium instead of the virgin metal. Aluminium does perform better but is expensive and a high embodied energy material.

6.1.8 Electrical

1. (a) **Unplasticised PVC** is an eco-friendly type evolved off the much popular PVC. With no visual difference between PVC and uPVC, it is necessary to confirm with the manufacturers specification data sheets. uPVC can be easily recycled or disposed at the end of its life cycle. This nature of the material to be easily recycled, reduces the burden on the natural resources for making the basic compound, unlike PVC which needs to undergo a highly energy consuming process for recycling. High-density polyethylene (HDPE) plastics perform similar to the uPVC compound. With similar performance and durability standards as compared to the conventional plastics and no significant cost deviations, these alternatives are a much-preferred choice.

1. (b) The use of **recycled metals** such as brass, aluminium and steel significantly reduce the burden on the natural resources. All metals consume massive amounts of energy for manufacturing. These embodied energies can be reused through the recycle and reuse process. Most of the metals can be completely recycled and hence 60-70% energy savings can be achieved, sometimes in excess of 95% like in the case of aluminium. It is a good practice to use products made using recycled metals and one should insist for a manufacturers specification certifying the use of such metals.

6.1. 9 Water Supply, Sanitary and Plumbing System

1. (a) Lead and Asbestos Cement pipes have high occupational hazard levels associated with them. Both materials feature in the list of 'most contaminating and hazardous materials', and their usage should be limited or restricted. Alternatives such R.C.C., uPVC and cast iron pipes display equivalent levels of performance and longevity. Lead can be replaced by the use of galvanised iron pipes and castings. Replacing asbestos cement pipes by the recommended alternatives does cost about 2-6 times depending on the usage, whereas replacing lead pipes reduces the costs by about 40-60%. The commonly used pipe listed below give a cost comparison over the entire range of materials available.

Table 6.6 - Cost Comparison of Piping Alternatives

Material	Cost Rs./R.Mt.	Cost Deviation (%)
A.C. Pipe 100mm dia.	48	Base
R.C.C. Pipe Np2 class 100mm dia.	120	+ 150
G.I. Pipe Heavy Type 100mm dia.	526	+ 995
G.I. Pipe Medium Type 100mm dia.	465	+ 868
C.I. Soil Pipe 100mm dia.	300	+ 525
C.I. Rain Water Pipe 100mm dia.	245	+ 410
uPVC Pipe 110mm dia.	98	+ 104
Stoneware Pipe 100mm dia.	48	<>
Half round Earthenware / Chinaware Pipe 100mm dia.	55	+ 115
Lead Pipe 25mm dia.	177	Base
G.I. Medium Type 25mm dia.	105	- 41
G.I. Heavy Type 25mm dia.	110	- 38
uPVC Pipe 25mm dia.	26	- 78
Polymer Plastic (Random) Pipe 25mm dia.	80	- 55

2. (a) Refer note 6.1. 8- 1.(b)

2. (b) A relatively new product in the market, the **Polymer Plastic (random) – PP(R)** pipes are a good alternative to the galvanised iron pipes and fittings conventionally used. The PP(R) pipes have a high hot water carrying capacity hence can replace the G.I. piping system completely. Simple jointing methods such as thermo-welding, makes it easier and faster to assemble the PP(R) piping system, almost 4 times faster than the G.I. system. The thermo-welded joints render the entire piping jointless once complete, hence no leakages. This alternative system most suitable for carrying drinking water owing to its excellent corrosion and chemical resistance, bacteriological neutrality, resistance to scaling of limestone, resistance to frost and bad electrical conductivity. Its lightweight reduces dead loads and handling and labour requirements. With a durability comparable with the G.I. system and a higher performance level, this recommended alternative is a better choice. Moreover, the PP(R) system can be easily compatible with the existing G.I. systems.

2. (c) The conventional use of cast iron chamber and manhole covers is much more expensive, energy consuming and non-eco-friendly than the recommended alternatives – precast R.C.C. and uPVC covers. Being a proven technology, precast R.C.C. is almost 50-60% cheaper than the cast iron system, while the uPVC covers cost about 30-50% cheaper. With precast R.C.C. and uPVC covers available in a varying range of sizes and load carrying capacities, the use of cast iron components can be considerably reduced. The table below indicates product prices and their comparisons.

Table 6.7 - Cost Comparison of Manhole Cover Alternatives

Material	Cost (Rs./Piece)	Cost Deviation (%)	
		50% C.I. + 50% Alt.	25% C.I. + 75% Alt.
C.I. Manhole Cover Medium Type 3'x1'6"	2,064	Base	Base
C.I. Manhole Cover Heavy Type 3'x1'6"	3,026	+ 23	+ 35
Precast R.C.C. Medium Type Manhole 3'x1'6"	211	- 45	- 67
PVC Manhole 2'8" dia. Circular	850	- 30	- 45

6.1. 10 Wood Work

1. (a) Alternative timber sources – refer to point 6.7.3(a)

1. (b) A number of thin veneers or plies of softwood or hardwood are glued together to make plywood. A suitable binder such as urea formaldehyde or phenol formaldehyde is usually used in the process. Depending upon the binder used, variations in the characteristics and behaviour of plywood can be achieved. Plywood, during its life cycle emits harmful volatile organic compounds like formaldehyde. Phenol bonded plywood have lower emission quantities as compared to the urea bonded types, hence one should make an effort to insist on a phenol bonded plywood and also confirm the binder compound by checking the manufacturers specifications and data sheets. Plywood being a good replacement for timber planks is consumed at an extremely high rate in India today; hence care must be taken to reduce the emission levels through out its life cycle. It is visually impossible to differentiate between plywood made using different binders, hence verification and / or certification from the manufacturer is a must.

2. (a) **Medium Density Fibre Board** (MDF) is abundantly used today as a replacement for plywood and wood planks. A more eco-sensitive option than plywood, MDF displays similar characteristics that make it a good alternative. Plywood and MDF contribute in reducing the consumption of wood to a great extent, but their manufacturing itself is highly energy driven. MDF is preferred over plywood for the simple reason that it is more environmentally friendly. It uses wood fibre from sawmill waste and wood chip fibres and other wood fibre wastes. MDF being a lighter board requires lesser support framing and also reduces dead loads on the structure. With same life spans and approximately the same costs, MDF surely out performs on the eco-sensitive aspects.

It is difficult to dispose or recycle MDF at the end of its life. It can easily be reused or salvaged. The binder, similar to the binders in plywood, makes MDF non-biodegradable and the process of separating the fibre and the binder is an energy intensive process. Therefore other wood alternatives mentioned below are preferred over MDF and plywood. Refer below for a cost comparison between wood alternatives.

2. (b) Wood alternatives, such as bagasse boards, finger jointed plantation board, bamboo ply board, fibre reinforced polymer board etc., are an excellent means of reducing the natural resource depletion and waste generation, which clearly is associated with the conventional products such as timber and plywood. Most of these products are based of techniques and process that convert large amounts of industrial and agro wastes into useful alternatives such as boards, tiles, mouldings etc. Also these innovative products consume much lesser amounts of manufacturing energy. They are either polymer bonded or pressure heated products, hence can be easily recycled or disposed at the end of their life spans. With a high aesthetic value of these products and a not so varying price range, these alternatives display a high fitness level for the purpose. The table 6.11 below lists some of the wood alternatives that have similar performance and durability levels.

2. (c) Using laminates and veneers as surface finishes is an effective practice for reducing the use of natural timber. Applying laminates or veneers on their surfaces, to achieve a wooden finish, can finish all wood alternatives and composite boards. An alternative board or composite can directly replace most applications of wood, unless the volumetric bulk of natural timber is required. The superficial wood look alike helps reduce wood consumption and treatment involved while using the natural material. Moreover, such surface finish can be made water resistant and also texture can be imparted as desired by the user. With durability in excess of 75% as that of natural timber and total costs reducing by 50% or more, laminated alternatives should be the preferred choice.

Table 6.8 - Cost Comparison of Wood Alternatives

Material	Cost (Rs./Sq.Ft.)	Cost Deviation (%)		
		75%Plywood + 25% Alt.	50%Plywood + 50% Alt.	25%Plywood + 75% Alt.
Plywood Commercial 12mm thick	35	Base	Base	Base
Plywood Marine 12mm thick	45	+ 7	+ 14	+ 21
MDF 12mm thick	30	- 4	- 7	- 11
Coir Composite MDF Board 12mm thick	44	+ 6	+ 13	+ 19
Bamboo Matt Ply Board 12mm thk	90	+ 39	+ 79	+ 118
Recycled Laminated Tube Board 12mm thick	86	+ 36	+ 73	+ 109

Recycled Aluminium Foil+Paper+Plastic Composite Board 12mm thick	68	+ 24	+ 47	+ 71
Rubber Wood Finger Jointed Board 12mm thick	95	+ 43	+ 86	+ 129
Bamboo MDF Board 11mm thick	125	+ 64	+ 128	+ 192
Block Board 30mm thick	75	+ 29	+ 57	+ 86
Particle Board (B.W.P.) 12mm thick	25	- 7	- 14	- 21
Single side laminated particle board 12mm thick	45	+ 7	+ 14	+ 21
Both side laminated particle board 12mm thick	52	+ 12	+ 24	+ 36
Cement Bonded Particle Board	27	- 6	- 12	- 18
Bamboo Matt Veneer Composite	NA	NA	NA	NA
Bagasse Board	NA	NA	NA	NA
Fibre Reinforced Polymer Board	NA	NA	NA	NA
Red Mud Composite Board	NA	NA	NA	NA

6.1.11 Water proofing chemicals, additives, sealants and adhesives

1. (a) **Water based compounds** have the same performance and durability properties as their conventional solvent based counterparts. All chemicals, water proofing compounds, sealants, paints and adhesives have two basic components – base compound and curing agent. On application the curing agent evaporates triggering a chemical reaction that leaves the base compound as a residual layer. These evaporating components have high harmful levels of volatile organic compounds and other pollutants and contaminants. These emissions can be reduced or eliminated through alternative curing agents. Water as a curing agent has absolutely no harmful emissions and thus out performs the other category of compounds such as acrylic, phenol or oil based. A wide range of water based products and compounds available in the market have no cost variations from the conventional ones.

2. (a) **Epoxy Resin** : Tar felt / paper and pitch have always been associated with water proofing in structures. The bitumen-based products basically have a high energy consuming manufacturing process and use huge amounts of natural resources. An eco-friendly replacement for such applications is through the use of epoxy resin systems. These resins are an eco-friendly alternative, consuming lower energies throughout their lives and are easily disposable or recyclable. Lower occupational hazards and emission levels add to its advantages. The only drawback is the 7-10 times increase in costs. This increase can be justified by the overall life cycle performance of the alternative.

6.1. 12 Painting, Polishing, Priming and similar surface finishing

1. (a) External surface finishing plays an important role in the overall performance of the structure. Water resistance, thermal properties, surface integrity and appearance are some of the key properties that the finish should cater to. Cement paints and epoxy resins display high performance levels when evaluated under the above-mentioned points. By eliminating the solvent based chemicals and finishing compounds, the emission levels can be reduced considerably. Moreover, these alternatives are easily recyclable and reused at the end of their lives. Cement paints can cost about 20-40% cheaper whereas the epoxy resin system could cost about twice as that of the conventional products used. A comparison of indicative costs is listed in the table below in point 5.12(b).

1. (b) Water based compounds have the same performance and durability properties as their conventional solvent based counterparts. All chemicals, water proofing compounds, sealants, paints and adhesives have two basic components – base compound and curing agent. On application the curing agent evaporates triggering a chemical reaction that leaves the base compound as a residual layer. These evaporating components have high harmful levels of volatile organic compounds and other pollutants and contaminants. These emissions can be reduced or eliminated through alternative curing agents. Water as a curing agent has absolutely no harmful emissions and thus out performs the other category of compounds such as acrylic, phenol or oil based. A wide range of water based products and compounds available in the market have no cost variations from the conventional ones. The table below indicates some of the types of surface finish used and their indicative cost comparisons.

Table 6.9 - Cost Comparison of Surface Finish Alternatives

Material	Cost Rs./unit	Unit	Cost Deviation (%)
Ready Mix Synthetic Paint	115	LTR.	Base
Oil Bound Distemper	70	KG.	- 39
Dry Distemper	42	KG.	- 63
Synthetic Distemper	60	KG.	- 48
Acrylic Distemper	68	KG.	- 41
Acrylic Plastic Emulsion	150	LTR.	+ 30
Acrylic Plastic Paint (grade I)	280	LTR.	+ 143
Oil Enamel Paint	156	LTR.	+ 36
Oil Paint (grade I)	130	LTR.	+ 13
Lustre Paint	175	LTR.	+ 52
Exterior Emulsion	230	LTR.	+ 100
Cement Paint	55	KG.	- 52
Polyurethane Enamel	130	LTR.	+ 13
Epoxy Resin System	340	LTR.	+ 196

The above table indicates the costs for some commonly used surface finishes. With varying methods of application, these compounds have different sale units (weight or volume). By a general understanding the application area for a 1kg. or 1LTR. pack of the above mentioned compounds ranges between 12-15 square meters of surface. Hence their costs can be compared over a range of varying sale units.

6.2 Building Material Cost Deviation and Comparison

The following table provides a tabular comparison of the cost of the various building material with basic prices and the percentage deviation. A positive percentage indicates a increase in the cost and a negative percentage indicates a lesser cost than the conventional materials.

Table 6.10 - Building Material Cost Deviation and Comparison

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
	Structural System - *Cement Concrete (plain / reinforced) - cement, sand, aggregate, steel*[1]						
	Base Materials for R.C.C. and Steel Systems						
5.1.1	**Mandatory**						
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)			5	25	
		Ordinary Portland Cement	M.T.	3000			Base
		Flyash	M.T.	1700			-11
5.1.2	**Non-Mandatory**						
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)			5	30,50	
		Ordinary Portland Cement	M.T.	3000			Base
		Flyash	M.T.	1700			-13, -22
	b	Sand and aggregate from pulverized debris and / or sintered flyash for concrete and mortar (equivalent to coarse and fine aggregates from natural sources as per IS383)			2,3,4	25,50,75	
		Sand, Natural	M.T.	380			Base
		Pulverized debris, sand	M.T.	100			- 18, - 37, - 55
		Aggregate, Natural	M.T.	147			Base
		Pulverized debris, aggregate	M.T.	100			-8, -16, - 24
	c	Recycled steel forms and reinforcement bars (steel reinforcement bars as per IS432,1785,1786 and high tensile structural steel as per IS961)	--		6,8	50,75	<>
	Alternative Systems						
5.1.3	**Non-Mandatory**						
	a	Ferro cement and / or Precast components[2] for columns, beams, slabs, staircases, lofts, balconies, roofs etc. (precast components as per IS13990,14201 and 3201)			5,10,15	25,50,75	
		Ferro Cement Components	--	20-30% less[7]			-8, -15, - 23
		Pre-cast Components	--	30-40% less[7]			- 10, - 20, -30
	b	Ready Mix Concrete					
		Concrete Mix, On Site	CU.MT.	2025			Base
		Ready Mix Concrete	CU.MT.	420	4,6	50,75	-40, - 59
	c	Use Resinous curing agents			2,4	25,50	
		Curing Agent, Powder	KG.	75			Base
		Epoxy Resin System	LTR.	340			+88, +176
		Phenalkamine Curing Agent	LTR.	380			+101, +203

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
		Masonry – *fired clay bricks, cement concrete blocks, stone*					
5.2		**Non-Mandatory**					
	a	Use of Fly ash + sand + lime bricks / blocks (IS4139), Pulverized debris + cement bricks / blocks, Industrial waste based bricks / blocks, Aerated lightweight BPC concrete blocks (IS2185), Phospho-Gypsum based blocks (IS12679) and Lato blocks (laterite + cement; IS12440), indiviually or in combination. (Artificial lightweight aggregates for concrete masonry blocks as per IS9142)			4,8,12	25,50,75	
		Brick, Fired Clay (225x150x100mm)	CU.MT.	1007			Base
		Cement Concrete Block (100x240x650mm)	CU.MT.	3462			+61, +122, +185
		Aerated Cement Concrete Block (100x240x650mm)	CU.MT.	3462			+61, +122, +185
		Flyash+sand+lime brick / Industrial waste based brick (225x150x80mm)	CU.MT.	1851			+20, +42, +63
		Pulverized Debris+cement bricks (225x150x80mm)	CU.MT.	1300			+7, +15, +22
		Phospho-Gypsum Based	CU.MT.	NA			NA
		Lato Blocks	CU.MT.	NA			NA
		Mortar – *cement, sand*					
5.3.1		**Mandatory**					
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)			3	25	
		Ordinary Portland Cement	M.T.	3000			Base
		Flyash	M.T.	1700			-11
5.3.2		**Non-Mandatory**					
	a	Sand from pulverized debris and / or sintered flyash (equivalent to natural sand / crushed stone sand as per IS2116)			2,3,4	25,50,75	
		Sand, Natural	M.T.	380			Base
		Pulverized debris, sand	M.T.	100			-18, -27, -55
	b	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)			3	30,50	
		Ordinary Portland Cement	M.T.	3000			Base
		Flyash	M.T.	1700			-13, -22
		Plastering – *Cement, sand, plaster of paris, gypsum*					
5.4		**Non-Mandatory**					
	a	Calcium Silicate Plaster			2,3	25,50	
		Gypsum Plaster Board (10mm thick)	SQ.FT.	12			Base
		P.O.P. Board (10mm thick)	SQ.FT.	12			<>
		Calcium Silicate Plaster Boards (10mm)	SQ.FT.	25			+27, +54
	b	Cement Plaster[2] (BPC based and sand for plaster as per IS1542)			1,2	25,50	
		Ordinary Portland Cement	M.T.	3000			Base
		Flyash	M.T.	1700			-13, -22
	c	Use of Fiber reinforced clay plaster/ Phospho-Gypsum Plaster (IS12679)/ Non-erodable Mud Plaster	SQ.FT.	NA	2,4	25,50	NA

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
	d	Use Resinous curing agents			2,4	25,50	
		Curing Agent, Powder	KG.	75			Base
		Epoxy Resin System	LTR.	340			+88, +176
		Phenalkamine Curing Agent	LTR.	380			+101, +203
		Roofing and ceiling – *R.C.C., Ferrous / non-ferrous sheets, tiles, thatch, composites like poly carbonate and PVC*					
5.5		**Non-Mandatory**					
	a	Fibre Reinforced Polymer Plastics instead of PVC and Foam PVC, Polycarbonates, acrylics & plastics			1,2	25,50	
		PVC sheet, Plain	SQ.FT.	45			Base
		Foam PVC (10mm)	SQ.FT.	90			+25, +50
		Polycarbonate Sheet	SQ.FT.	70			+14, +28
		Acrylic	SQ.FT.	40			-3, -6
		FRP	SQ.FT.	60			+8, +17
	b	Micro Concrete Roofing Tiles and/or Bamboo Matt Corrugated Roofing Sheets			3,5	50,75	
		Galvanised Iron Corrugated sheets on steel support	SQ.FT.	40			Base
		Asbestos Cement Corrugated Sheets on steel supports	SQ.FT.	37			-4, -6
		Aluminium Corrugated sheets on steel supports	SQ.FT.	53			+16, +24
		Mangalore Tiles on Primary Wood supports	SQ.FT.	48			+10, +15
		PVC Corrugated sheet on steel support	SQ.FT.	42			+2, +3
		MCR Tile on steel support	SQ.FT.	33			-9, -13
		MCR Tile on Primary Wood support	SQ.FT.	36			-5, -7.5
		Bamboo Matt Corrugated Sheet on Primary Wood support	SQ.FT.	45			+6, +9
		Flooring, paving and road work – *wood, stone, ceramics, carpets, composites, concrete*					
5.6		**Non-Mandatory**					
	a	Fly ash / industrial waste / pulverized debris blocks in BPC and/or lime-pozzolana concrete paving blocks (as per IS10359) to be used for all outdoor paving (as per IS7245)			2,4	50,75	
		Cement Concrete Paving Block (50mm thick)	SQ.FT.	25			Base
		Flyash+sand+lime Paving Block (50mm thick)	SQ.FT.	25			<>
		Pulverized Debris+Cement Paving Block (50mm thick)	SQ.FT.	22			-6, - 9
	b	Bedding sand for pavement and outdoor hard surfaces from pulverized debris			2,4	50,75	
		Sand, Natural	M.T.	380			Base
		Pulverized debris, sand	M.T.	100			-37, -55
	c	Terrazzo floor for terraces and semi covered areas (IS2114)			2,4	50,75	refer to point 5.6 (d)
	d	Use Ceramic tiles (non-vitrified)(IS 13712)/ Mosaic Tiles/ Terrazzo Flooring (IS2114)/ Cement Tiles (IS1237, 3801)/ Phospho-Gypsum Tiles (IS12679)/ Bamboo Board Flooring, individually or in combination for interior spaces.			2,3	50,75	
		Vitrified Ceramic Tile	SQ.FT.	75			Base
		Marble Flooring	SQ.FT.	125			+33, +50
		Granite Flooring	SQ.FT.	125			+33, +50
		Kota Stone, 30mm thick - machine cut - one side polish	SQ.FT.	35			-27, -40
		Vinyl Flooring	SQ.FT.	60			-10, -15
		Bamboo Board Flooring	SQ.FT.	150			+50, +75

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
		Terrazzo Flooring	SQ.FT.	29			-31, -46
		Marble Mosaic Tiles	SQ.FT.	20			-37, -55
		White Glazed Tiles (dado)	SQ.FT.	15			-40, -60
		Ceramic (non-vitrified) Tiles	SQ.FT.	30			-30, -45
		Plain Cement Tiles	SQ.FT.	13			-41, -62
	Windows, Doors and openings – *Steel, aluminum, timber, glass, R.C.C., PVC, Stone*						
5.7.1	**Non-Mandatory**						
	a	Ferro cement and Precast R.C.C. lintel (IS9893), chajja and jalis[2]			4,6	50,75	
		Ferro Cement Components	--	20-30% less[7]			- 8, -15, -23
		Pre-cast Components	--	30-40% less[7]			-10, -20, -30
	b	Masonry bond combinations for jali work (achievable in rat trap bond)			1,2	50,75	NA
	Timber and Aluminum / Steel frames to be replaced by -						
5.7.2	**Non-Mandatory**						
	a	Ferrocement and Precast R.C.C. Frames (as per IS6523)/ Frameless Doors (IS15345) and/or Bamboo Reinforced Concrete Frames[2]			4,6	50,75	
		Ferro Cement Components	--	20-30% less[7]			-8, -15, -23
		Pre-cast Components	--	30-40% less[7]			-10, -20, -30
		Bamboo Reinforced Concrete Components	--	lesser[7]			NA
	b	Hollow recycled steel channels (IS1038,7452) and Recycled Aluminium Channels (IS1948) and Components			2,4	50,75	<>
	Shutters and Panels – timber, plywood, glass, aluminum						
5.7.3	**Mandatory**						
	a	Timber used must be renewable timber from plantations with species having not more than 10 year cycle or timber from a government certified forest / plantation or timber from salvaged wood			3	100	
		Burma Teak	CU.FT.	1800			Base
		Rose Wood	CU.FT.	3500			+94
		Cedar Pine Wood	CU.FT.	850			-53
		Silver Oak Wood	CU.FT.	280			-84
		Deodar	CU.FT.	450			-75
		Sal Wood	CU.FT.	550			-69
		Eucalyptus Wood	CU.FT.	750			-58
		Rubber Wood	CU.FT.	450			-75
5.7.4	**Non-Mandatory**						
	a	Use of MDF Board (IS12406)			1,2	25,50	refer to point 5.7.4 (c)
	b	Use any of the following individually or in combination - Red Mud based Composite door shutters, Laminated Hollow Composite Shutters, Fibre Reinforced Polymer Board, Coir Composite Board (Medium Density IS 15491), Bamboo Mat Board (IS 13958), Bamboo mat Veneer Composite (IS 14588), Bagasse Board, Finger Jointed Plantation Board, Recycled Laminated Tube Board and Aluminium Foil+Paper+Plastic Composite Board			9,12	50,75	refer to point 5.7.4 (c)

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
	c	Use PVC/ FRP Doors (IS14856)/ poly carbonate and/or recycled aluminum components in wet areas. FRP is the best option			2,3	50,75	
		Solid Core Shutter 35mm thick with veneer	SQ.FT.	85			Base
		Laminated Hollow Composite Shutter	SQ.FT.	175			+26, +53, +79
		Plywood Commercial 12mm thick	SQ.FT.	35			Base
		Plywood Marine 12mm thick	SQ.FT.	45			+7, +14, +21
		MDF 12mm thick	SQ.FT.	30			-4, -7, -11
		Coir Composite MDF Board 12mm thick	SQ.FT.	44			+6, +13, +19
		Bamboo Matt Ply Board 12mm thick	SQ.FT.	90			+39, +79, +118
		Recycled Laminated Tube Board 12mm thick	SQ.FT.	86			+36, +73, +109
		Recycled Aluminium Foil+Paper+Plastic Composite Board 12mm thick	SQ.FT.	68			+24, +47, +71
		Rubber Wood Finger Jointed Board 12mm thick	SQ.FT.	95			+43, +86, +129
		Bamboo MDF Board 11mm thick	SQ.FT.	125			+64, +128, +192
		Block Board 30mm thick	SQ.FT.	75			+29, +57, +86
		Particle Board (B.W.P.) 12mm thick	SQ.FT.	25			-7, -14, -21
		Single side laminated particle board 12mm thick	SQ.FT.	45			+7, +14, +21
		Both side laminated particle board 12mm thick	SQ.FT.	52			+12, +24, +36
		Cement Bonded Particle Board	SQ.FT.	27			-6, -12, -18
		Bamboo Matt Veneer Composite	SQ.FT.	NA			NA
		Bagasse Board	SQ.FT.	NA			NA
		Fibre Reinforced Polymer Board	SQ.FT.	NA			NA
		Red Mud Composite Board	SQ.FT.	NA			NA
		PVC sheet, Plain	SQ.FT.	45			+7, +14, +21
		Foam PVC (10mm)	SQ.FT.	90			+39, +79, +118
		Polycarbonate Sheet	SQ.FT.	70			+25, +50, +75
		Acrylic	SQ.FT.	40			+4, +7, +10
		FRP	SQ.FT.	60			+18, +36, +54
	Electrical – A*luminum, brass, PVC, G.I., S.S.*						
5.8	**Non-Mandatory**						
	a	Use unplasticised PVC or HDPE products			5	75	<>
	b	Where applicable use products with recycled aluminum and brass components			5	75	<>
	Water supply, Sanitary and Plumbing System						
5.9.1	**Mandatory**						
	a	R.C.C., uPVC (IS15328), G.I., C.I. pipes instead of lead, A.C. pipes (100%)			5	100	
		A.C. Pipe 100mm dia.	R.MT.	48			Base
		R.C.C. Pipe Np2 class 100mm dia.	R.MT.	120			+150
		G.I. Pipe Heavy Type 100mm dia.	R.MT.	526			+995
		G.I. Pipe Medium Type 100mm dia.	R.MT.	465			+868
		C.I. Soil Pipe 100mm dia.	R.MT.	300			+525
		C.I. Rain Water Pipe 100mm dia.	R.MT.	245			+410
		uPVC Pipe 110mm dia.	R.MT.	98			+104
		Stoneware Pipe 100mm dia.	R.MT.	48			0
		Half round Earthenware / Chinaware Pipe 100mm dia.	R.MT.	55			+15

		Lead Pipe 25mm dia.	R.MT.	177			Base
		G.I. Medium Type 25mm dia.	R.MT.	105			+ 41
		G.I. Heavy Type 25mm dia.	R.MT.	110			- 38
S. No.		**Description and Measure**	**Unit**	**Indicative Cost (Rs.)**	**Points**	**Usage %**	**Cost Deviation (conventional materials fixed at Base 100%)[8]**
		uPVC Pipe 25mm dia.	R.MT.	26			- 78
		Polymer Plastic (Random) Pipe 25mm dia.	R.MT.	80			-55
5.9.2	**Non-Mandatory**						
	a	Where applicable use products with recycled aluminum and brass components for fittings, fixtures and accessories			1,2	50,75	<>
	b	Use Polymer Plastic (Random) (ISO EN 15874) hot / cold water system instead of G.I.			2,3	50,75	
		G.I. Medium Type 25mm dia.	R.MT.	105			Base
		G.I. Heavy Type 25mm dia.	R.MT.	110			+2, +3.5
		Polymer Plastic (Random) Pipe 25mm dia.	R.MT.	80			-12, -18
	c	Manholes and covers - use Precast cement concrete and high strength unplasticised PVC instead of C.I. (as per IS12592)			3,4	50,75	
		C.I. Manhole Cover Medium Type 3'x1'6"	PIECE	2,064			Base
		C.I. Manhole Cover Heavy Type 3'x1'6"	PIECE	3,026			+23, +35
		Precast R.C.C. Medium Type Manhole 3'x1'6"	PIECE	211			-45, -67
		PVC Manhole 2'8" dia. Circular	PIECE	850			-30, -45
	Wood Work - *Plywood and Natural Timber*						
5.10.1	**Mandatory**						
	a	Timber used must be renewable timber from plantations with species having not more than 10 year cycle or timber from a government certified forest / plantation or timber from salvaged wood			4	100	
		Burma Teak	CU.FT.	1800			Base
		Rose Wood	CU.FT.	3500			+94
		Cedar Pine Wood	CU.FT.	850			- 53
		Silver Oak Wood	CU.FT.	280			-84
		Deodar	CU.FT.	450			-75
		Sal Wood	CU.FT.	550			-69
		Eucalyptus Wood	CU.FT.	750			- 58
		Rubber Wood	CU.FT.	450			-75
	b	If Plywood is used, it should be phenol bonded and not urea bonded			2	100	<>
5.10.2	**Non-Mandatory**						
	a	Use of MDF Board (IS12406)			1,2	25,50	refer to point 5.10.2 (c)
	b	Use any of the following individually or in combination - Bamboo Ply/Mat Board (IS 13958), Fibre Reinforced Polymer Board, Bagasse Board, Coir Composite Board (Medium Density IS 15491), Bamboo mat Veneer Composite (IS 14588), Finger Jointed Plantation Timber Board, Recycled Laminated Tube Board and Aluminium-Foil+Paper+Plastic Composite Board			6,8	50,75	refer to point 5.10.2 (c)
	c	Use of Mica Laminates and Veneer on Composite boards instead of natural timber.			3,4	50,75	
		Plywood Commercial 12mm thick	SQ.FT.	35			Base
		Plywood Marine 12mm thick	SQ.FT.	45			+7, +14, +21
		MDF 12mm thick	SQ.FT.	30			- 4, -7, -11
		Coir Composite MDF Board 12mm thick	SQ.FT.	44			+6, +13, +19

S. No.		Description and Measure	Unit	Indicative Cost (Rs.)	Points	Usage %	Cost Deviation (conventional materials fixed at Base 100%)[8]
		Bamboo Matt Ply Board 12mm thick	SQ.FT.	90			+39, +79, +118
		Recycled Laminated Tube Board 12mm thick	SQ.FT.	86			+36, +73, +109
		Recycled Aluminium Foil+Paper+Plastic Composite Board 12mm thick	SQ.FT.	68			+24, +47, +71
		Rubber Wood Finger Jointed Board 12mm thick	SQ.FT.	95			+43, +86, +129
		Bamboo MDF Board 11mm thick	SQ.FT.	125			+64, +128, + 192
		Block Board 30mm thick	SQ.FT.	75			+29, + 57, +86
		Particle Board (B.W.P.) 12mm thick	SQ.FT.	25			-7, -14, -21
		Single side laminated particle board 12mm thick	SQ.FT.	45			+7, +14, +21
		Both side laminated particle board 12mm thick	SQ.FT.	52			+12, +24, +36
		Cement Bonded Particle Board	SQ.FT.	27			-16, -12, -18
		Bamboo Matt Veneer Composite	SQ.FT.	NA			NA
		Bagasse Board	SQ.FT.	59			+13, +27, +41
		Fibre Reinforced Polymer Board	SQ.FT.	75			+17, +35, +52
		Red Mud Composite Board	SQ.FT.	NA			NA
		Mica Laminate 1mm thick	SQ.FT.	23-30			<>
		Natural Veneer	SQ.FT.	38			<>
	Water proofing chemicals, additives, sealants and adhesives						
5.11.1	**Mandatory**						
	a	Use of water based chemicals instead of solvent based. (100%)			3	100	<>
5.11.2	**Non-Mandatory**						
	a	Epoxy resins instead of tar felt / pitch			2,3	50,75	
		Tar Paper	SQ.FT.	2.5			Base
		Tar Felt	SQ.FT.	3.5			+14, +22
		Tarpauling Sheet	SQ.FT.	2.5			<>
		Water Proofing Polymer	SQ.FT.	2.5			<>
		Epoxy Layer System	SQ.FT.	58			+1000, +1500
	Painting, Polishing, Priming and similar surface finishing						
5.12	**Non-Mandatory**						
	a	Use of Cement Paint (IS5410)/ Epoxy Resin Paint for external surfaces			3,4	50,75	refer to point 5.12 (b)
	b	Use of Water based paints, enamels, primers and polishes			3,4	50,75	<>
		Ready Mix Synthetic Paint	LTR.	115			Base
		Oil Bound Distemper	KG.	70			- 20, -30
		Dry Distemper	KG.	42			-32, -48
		Synthetic Distemper	KG.	60			-60
		Acrylic Distemper	KG.	68			- 20, -30
		Acrylic Plastic Emulsion	LTR.	150			+15, +23
		Acrylic Plastic Paint (grade I)	LTR.	280			+72, +108
		Oil Enamel Paint	LTR.	156			+18, +27
		Oil Paint (grade I)	LTR.	130			+7, +10
		Lustre Paint	LTR.	175			+26, +39
		Exterior Emulsion	LTR.	230			+50, +75
		Cement Paint	KG.	55			- 26, -39

	Polyurethane Enamel	LTR.	130			+7, +10
	Epoxy Resin System	LTR.	340			+98, +147

Notes:

1	Materials in Italics are the conventionally used materials, eco-friendly alternatives to these have been suggested.
2	In case of ferrocement, precast cement concrete and cement plaster, reinforcement steel used must be recycled steel and cement used must be a blended portland cement type or ordinary portland cement blended with raw pozzolana material. These criteria are mandatory. The material requirements for ferrocement and precast cement concrete usage shall be evaluated under criteria no. 1.1(a,b,c).
3	Wherever Flyash has been suggested as alternative the quality of Flyash used should be as per IS 3812.
4	The usage % values indicate the amount of material used for that specific activity / category / component it falls under. The scope of the points scored against a particular material is limited to the activity specified.
5	Submittal requirement for the building materials is the Bill of Quantities showing the total quanity of material required in each category and the total quantity of the recommended alternatives purchased
6	All alternative materials and techniques must be certified as per the IS codes or other international code specified. In case a code of standard is not specified, the alternative shall have equivalent properties as specified in the codes for the material / technique it substitutes. The Architect / Builder / Contractor / Developer will be responsible for maintaining material, product and workmanship standards in compliance with the BIS codes or other international standards such as ISO, ASTM and BS. Any claims arising due to poor quality of construction shall be dealt with by the architect / builder / contractor / developer directly with the complainant.
7	The lesser cost is in comparison with the conventional R.C.C. technology
8	The cost comparison values listed correspond to the usage % values specified. The costing values are percentage values relative to conventional materials based at 100%. If a material has value 89 in the costing column corresponding to 25% usage, that means, the cost of the activity would be 89% of the conventional technique / material if the alternative is used to an extent of 25%.

Indicators

	reccomended alternative material / product / technique
<>	no relative cost deviation

6.3 Environmental Impact

The overall environmental benefits of the measure have been estimated at four levels – Household level, Building level, City level and at a global level. The table below summaries the same below:

Table 6.11 -Environmental Impact

S. No.		Description and Measure	Environmental Impact			
			House	Building	City	Global
		Structural System - *Cement Concrete (plain / reinforced) - cement, sand, aggregate, steel*[1]				
		Base Materials for R.C.C. and Steel Systems				
5.1.1		**Mandatory**				
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)				
5.1.2		**Non-Mandatory**				
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)				
	b	Sand and aggregate from pulverized debris and / or sintered flyash for concrete and mortar (equivalent to coarse and fine aggregates from natural sources as per IS383)				

S. No.		Description and Measure	Environmental Impact: House	Building	City	Global
	c	Recycled steel forms and reinforcement bars (steel reinforcement bars as per IS432,1785,1786 and high tensile structural steel as per IS961)				
		Alternative Systems				
5.1.3		**Non-Mandatory**				
	a	Ferro cement and / or Precast components[2] for columns, beams, slabs, staircases, lofts, balconies, roofs etc. (precast components as per IS13990,14201 and 3201)				
	b	Ready Mix Concrete				
	c	Use Resinous curing agents				
		Masonry – *fired clay bricks, cement concrete blocks, stone*				
5.2		**Non-Mandatory**				
	a	Use of Fly ash + sand + lime bricks / blocks (IS4139), Pulverized debris + cement bricks / blocks, Industrial waste based bricks / blocks, Aerated lightweight BPC concrete blocks (IS2185), Phospho-Gypsum based blocks (IS12679) and Lato blocks (laterite + cement; IS12440), indiviually or in combination. (Artificial lightweight aggregates for concrete masonry blocks as per IS9142)				
		Mortar – *cement, sand*				
5.3.1		**Mandatory**				
	a	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)				
5.3.2		**Non-Mandatory**				
	a	Sand from pulverized debris and / or sintered flyash (equivalent to natural sand / crushed stone sand as per IS2116)				
	b	Pozzolana Material content (Flyash / Slag / Calcined Clay) attained through use of Blended Portland Cement (BPC) as per IS1489 (flyash and calcined clay based) and IS455(slag based) and / or direct addition of pozzolana material (flyash as per IS3812, Slag as per IS12089 and Calcined Clay as per IS1344)				
		Plastering – Cement, sand, plaster of paris, gypsum				
5.4		**Non-Mandatory**				
	a	Calcium Silicate Plaster				
	b	Cement Plaster[2] (BPC based and sand for plaster as per IS1542)				
	c	Use of Fiber reinforced clay plaster/ Phospho-Gypsum Plaster (IS12679)/ Non-erodable Mud Plaster				
	d	Use Resinous curing agents				
		Roofing and ceiling – *R.C.C., Ferrous / non-ferrous sheets, tiles, thatch, composites like poly carbonate and PVC*				
5.5		**Non-Mandatory**				
	a	Fibre Reinforced Polymer Plastics instead of PVC and Foam PVC, Polycarbonates, acrylics & plastics				
	b	Micro Concrete Roofing Tiles and/or Bamboo Matt Corrugated Roofing Sheets				
		Flooring, paving and road work – *wood, stone, ceramics, carpets, composites, concrete*				
5.6		**Non-Mandatory**				
	a	Fly ash / industrial waste / pulverized debris blocks in BPC and/or lime-pozzolana concrete paving blocks (as per IS10359) to be used for all outdoor paving (as per IS7245)				
	b	Bedding sand for pavement and outdoor hard surfaces from pulverized debris				
	c	Terrazzo floor for terraces and semi covered areas (IS2114)				

	d	Use Ceramic tiles (non-vitrified)(IS 13712)/ Mosaic Tiles/ Terrazzo Flooring (IS2114)/ Cement Tiles (IS1237, 3801)/ Phospho-Gypsum Tiles (IS12679)/ Bamboo Board Flooring, individually or in combination for interior spaces.				
	Windows, Doors and openings – *Steel, aluminum, timber, glass, R.C.C., PVC, Stone*					
5.7.1	**Non-Mandatory**					
	a	Ferro cement and Precast R.C.C. lintel (IS9893), chajja and jalis[2]				
	b	Masonry bond combinations for jali work (achievable in rat trap bond)				
	Timber and Aluminum / Steel frames to be replaced by -					
5.7.2	**Non-Mandatory**					
	a	Ferrocement and Precast R.C.C. Frames (as per IS6523)/ Frameless Doors (IS15345) and/or Bamboo Reinforced Concrete Frames[2]				
	b	Hollow recycled steel channels (IS1038,7452) and Recycled Aluminium Channels (IS1948) and Components				
	Shutters and Panels – timber, plywood, glass, aluminum					
5.7.3	**Mandatory**					
	a	Timber used must be renewable timber from plantations with species having not more than 10 year cycle or timber from a government certified forest / plantation or timber from salvaged wood				
5.7.4	**Non-Mandatory**					
	a	Use of MDF Board (IS12406)				
	b	Use any of the following individually or in combination - Red Mud based Composite door shutters, Laminated Hollow Composite Shutters, Fibre Reinforced Polymer Board, Coir Composite Board (Medium Density IS 15491), Bamboo Mat Board (IS 13958), Bamboo mat Veneer Composite (IS 14588), Bagasse Board, Finger Jointed Plantation Board, Recycled Laminated Tube Board and Aluminium Foil+Paper+Plastic Composite Board				

S. No.		Description and Measure	Environmental Impact			
			House	Building	City	Global
	c	Use PVC/ FRP Doors (IS14856)/ poly carbonate and/or recycled aluminum components in wet areas. FRP is the best option				
		Electrical – *Aluminum, brass, PVC, G.I., S.S.*				
5.8		**Non-Mandatory**				
	a	Use unplasticised PVC or HDPE products above 75%				
	b	Where applicable use products with recycled aluminum and brass components above 75%				
		Water supply, Sanitary and Plumbing System				
5.9.1		**Mandatory**				
	a	R.C.C., uPVC (IS15328), G.I., C.I. pipes instead of lead, A.C. pipes (100%)				
5.9.2		**Non-Mandatory**				
	a	Where applicable use products with recycled aluminum and brass components for fittings, fixtures and accessories				
	b	Use Polymer Plastic (Random) (ISO EN 15874) hot / cold water system instead of G.I.				
	c	Manholes and covers - use Precast cement concrete and high strength unplasticised PVC instead of C.I. (as per IS12592)				
		Wood Work - *Plywood and Natural Timber*				
5.10.1		**Mandatory**				
	a	Timber used must be renewable timber from plantations with species having not more than 10 year cycle or timber from a government certified forest / plantation or timber from salvaged wood				
	b	If Plywood is used, it should be phenol bonded and not urea bonded				
5.10.2		**Non-Mandatory**				
	a	Use of MDF Board (IS12406)				
	b	Use any of the following individually or in combination - Bamboo Ply/Mat Board (IS 13958), Fibre Reinforced Polymer Board, Bagasse Board, Coir Composite Board (Medium Density IS 15491), Bamboo mat Veneer Composite (IS 14588), Finger Jointed Plantation Timber Board, Recycled Laminated Tube Board and Aluminium-Foil+Paper+Plastic Composite Board				
	c	Use of Mica Laminates and Veneer on Composite boards instead of natural timber.				
		Water proofing chemicals, additives, sealants and adhesives				
5.11.1		**Mandatory**				
	a	Use of water based chemicals instead of solvent based. (100%)				
5.11.2		**Non-Mandatory**				
	a	Epoxy resins instead of tar felt / pitch				
		Painting, Polishing, Priming and similar surface finishing				
5.12		**Non-Mandatory**				
	a	Use of Cement Paint (IS5410)/ Epoxy Resin Paint for external surfaces				
	b	Use of Water based paints, enamels, primers and polishes				