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Materials For Sustainable Constructions:
Concrete And Masonry

الاســـتدامة فى أعمال التشـــييد
الخرسانة و الطوب

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ملخص البحث:

تتميز غالبية المواد صديقة البيئة بأنها ذات مظهر مميز . فهي صديقة للبيئة فى طريقة تصنيعها ، استخدامها ، واستعادتها بعد الاستخدام . و اهم الخصائص التى ينبغى ان تتواجد- كلها او بعضا منها- فى المادة لاعتبارها صديقة للبيئة هى : تحتوى على مواد قابلة لاعادة الاستخدام ، ان تكون من بدائل زراعية ، ليست ذات سمات سامة ، و ذات كفاءة فى استخدام الطاقة .

تهدف هذه الورقة البحيثة إلى الوصول الى استراتيجية لتحقيق مبدأ الاستدامة فى عمليات البناء و التشييد ، و خاصة فى مجال اختيار و توصيف مواد البناء التى لا تضر البيئة و لا تستنفذ مواردها الطبيعية . و لتحقيق هذا الهدف كانت هناك بعض الأهداف الفرعية : توضيح المعنى المقصود بالمواد صديقة البيئة ، ووضع السياسات التى تساعد فى اختيار مواد البناء التى تساعد فى تحسين الصفات البيئية و الإرتقاء بعمليات التشييد لتحقيق الإستدامة الفعلية بها ، ثم تطبيق تلك السياسات على بعض اعمال التشييد الخاصة بالخرسانة و الطوب .

قبل الثورة الصناعية حققت المجتمعات معظم احتياجاتها بمواد مستمدة من الأرض و ترابها و اعادتها الى الأرض مرة اخرى بعد استخدامها . و الان معظم المواد صديقة البيئة أثبتت وجودها و انها تستطيع تحقيق الاداء المطلوب منها مع قدرتها على المنافسة التسويقية و السعرية .

و تتمثل المبادئ الأساسية لتقييم مدى صداقة مواد البناء للبيئة فى النقاط الثلاث التالية : ادارة الموارد البيئية و الحفاظ على صحة المستخدمين ، و الأداء الوظيفى للمادة . و يجب ان يتم هذا التقييم البيئ لتاثير المادة خلال كامل دورة الحياة

الخاصة بها منذ استخلاصها من البيئة ، تصنيعها ، استخدامها ، واستعادتها او التخلص منها بعد انتهاء مدة الإستعمال .

ويجب ان تتضمن عملية اختيار مواد البناء على المراحل التالية : تحديد المجموعة التى تنتمى اليها المادة (خرسانة ، طوب ، معدن ، خشب ، ...) ، يلى ذلك تحديد البدائل المتاحة صديقة البيئة للمواد فى تلك المجموعة ، الحصول على المعلومات الفنية عن خصائص و مواصفات تلك البدائل المتاحة من مواد البناء ، التحقق من تلك المواصفات و استكمالها ، تقييم البدائل المتاحة ، ثم اختيار الأنسب بيئيا .

و من نتائـــج هذه الورقة البحثية نستطيع ان نجمل اسس اختيار المواد صديقة البيئة ، و التى يجب ان تتوفر فيها المبادئ الاتية :طول العمر و القدرة على التحمل ، الكفاءة الفائقة فى استخدام الطاقة ، القابلية الكبيرة لاعادة الاستخدام و امكانية عمليات

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الصيانة ، القدرة على استيعاب مواد معادة الإستخدام و التدوير ، الإهتمام بتوفير المواد المحلية و الإقليمية ، و تقليل الطاقة الكام بالمواد ، الحد من استخدام الكيماويات الطبيعية السامة و الكيماويات الصناعية .

و فى النهاية تعرض هذه الورقة البحثية كيفية استخدام مواد البناء من الخرسانة و الطوب بطريقة تضمن تحقيق مبدأ الإستدا فى عمليات التشييد و البناء .

تحقيق مبادئ الحفاظ عليها و حمايتها من معدلات الاستهلاك التى تهدد بنفاذها ، الخصائص الصحية للمادة و قدرتها على

bstract

There is a lot of imagery associated with the term "environmentally". Environmentally friendly products (Green oducts) -from the photovoltaic panels to the buildings made up of Aluminum cans and old tires- look distinctive. een building materials are green in the way they are manufactured, used, and recycled after use. What is meant here e alternative agricultural, recycled content, nontoxic, and energy efficient products that may display environmental ties. Prior to the industrial revolution, society met most of their needs with materials from the earth and then returned the earth after use. Nowadays, many green products are gaining ground in the mainstream. That means they could rform and are cost- competitive.

The aim of this paper is to reach a strategy to achieve sustainability in our daily construction operations particularly the field of selection and specifications of building materials that neither harm the environment nor exhaust the tural capacity or the resources. In order to attain this aim some objectives are targeted. These objectives include: rifying the meaning of greenness of building materials, setting up the guidelines for the selection of building terials that enhance the environmental quality and promote sustainable construction operations, and then applying the ategy on some kind of construction associated with concrete and masonry works. Principles of assessing the enness of building materials include: resource management, toxicity, and performance. The product selection ocess includes the following steps: identifying materials category (site construction, wood, masonry, concrete, ishes, mechanical, etc.), identifying green building materials options, gathering technical information, reviewing mitted information for completeness, evaluate materials, and select and document choice.

The conclusion of this paper can summarize the rules of selecting green building materials, the general rules are: ximizing the durability, maximizing the energy efficiency, maximizing the future recycleability, maximizing the intainability, maximizing the recycled content and closing the loop, maximizing the use of local and regional terials minimizing the embodied energy, minimizing the use of hazardous natural chemicals, and minimizing the use synthetic chemicals. Finally, the sustainable manners of using concrete different types and masonry units are lained in details within this search paper.

I. Introduction

Green building materials is a vital tool for creating environmentally friendly buildings, which are made from materials that conserve the earth's legacy for future generation. When selecting and specifying green building materials, architects need more than natural sense. They need advice on how to select non-toxic recycled and recyclable products, and how to integrate them into the design process to gain the practical and economic advantages of going green, from reducing waste and improving energy efficiency to promote proper code compliance.

II. What are green building materials?

They are green in the way they are manufactured, used, and regained after use. They use the earth's resources in environmentally responsible manner. They are nontoxic, made form recycled materials, and are themselves recyclable[1]. Green building materials have one or more of the following characteristics: nontoxic, recycled content, resource efficient, long life cycle, or environmentally consciousness[2]. The majority of building owners, designers, manufactures, building officials are not open to using green materials. Their pereeption of green building materials is that they look bad, cost a lot, and do not perform well. Therefore, we need to clarify what green building materials are and what they are not.

[1] Spiegel, R., and Meadows, D. (1999) Green Building Materials: A Guide to Product Selection and Specification, New York: John Wiley & Sons, Inc.

[2] Davison, M. et al. (2000), Green Building Materials Residence, Waterloo University.

III. Life-cycle assessment

Prior to the industrial revolution, societies met most of their needs with materials from the earth and then returned them to the earth after use. The evidence that green works is that many green products are gaining ground in the mainstream. That means they could perform and they are cost-competitive. The concept of greenness seeks alternative agricultural, recycled content, nontoxic, and energy-efficient products. Many products used for decades have contained recycled materials (acoustical ceiling tiles fabricated from re cycled cellulose, gypsum board form broken gypsum and recycled paper). Decision to aesthetic value depends on personal perception. Generally, there is variety in the market to make it true to consider aesthetically green building materials are neither better nor worse than conventional options. There is a concern about the initial cost of green product and its impacts on the value of the building investment. When discussing cost relative to environmental issues, we should consider broader societal cost resulting from the destruction of global commons, and the direct cost resulting from the individual. Economic companies show that green products are often competitive for purchase and installation[3].

Improving the environmental performance of a building requires a systemic and comprehensive understanding of all the environmental impacts that happen through the building's life-cycle. This approach,

[3] Spiegel, R., and Meadows, D. (1999) Green Building Materials: A Guide to Product Selection and Specification, New York: John Wiley & Sons, Inc.

characteristics. High-performance glazing- such as low emissivity glazing- minimizes the thermal transmission and improves the energy efficiency of the structure and reduces the pollution generated by electricity generators. This glazing utilizes PVC layers and Pyrolytic coating and while the glass is inert and recyclable, the manufacturing process is guilty of pollution, depletion, and destruction. So, assessment of building materials toxicity is sensitive and should be performed with care in respect to the different phases of the materials itself.

3. Performance

It investigates installation methods, maintenance, durability, energy efficiency, and ability of the product to be reused or recycled. It also includes the impacts on the global commons, such as the albedo of the exterior finishes and the permeability of the paving. Performance measurements include energy efficiency ratings, worker productivity, and customer satisfaction. Energy efficiency improvements mean less energy and less pollution. Durable products mean less replacement and less strain on resources. Mechanical fastening is preferable from an IAQ perspective and from the possibilities of disassembly for future reuse. Packaging operation should be reduced. Reuse of packaging is cost-effective. Reduction of packaging makes obvious economic sense and means less money spent and translates into profits. Cardboard with recycled content materials is preferred over petroleum-based plastics, Starch based plastics are new products for vacuum wrapping. Soy-based ink used in the printing of labels is preferred.

V. The product selection process

All the factors of quality, aesthetics, performance, and cost of the product should be explored. Next to that the impacts of the product on the environment should be explored. The standard product selection process includes the following steps[12]:

i. Identify materials category (site construction, masonry, wood, concrete, etc.)

ii. Identify green building materials options. Green options are available for every conventional building material. Green building materials source books are available[13] and much information is available via the Internet. For example Adobe masonry unit, Rammed Earth, and Straw Bale might be options for exterior masonry walls. Consider clay masonry fabricated from contaminated soil, or concrete fabricated with fly ash and slag. Also explore local options for natural stone.

iii. Gather technical information regarding the greenness of building products. Sources include: product representatives, governmental agencies, building codes, trade organizations, industry standards, materials safety data sheets, green

[12] Spiegel, R., and Meadows, D. (1999) Green Building Materials: A Guide to Product Selection and Specification, New York: John Wiley & Sons, Inc.

[13] Such as: 1: John, Hermann son (1997), Green Building Resource Guide, Turnton Press.
2: Construction and Demolition Waste Recycling Guide, Integrated Soil Waste Management Office, Los Angeles, CA.

biodegradable and tend to generate fewer pollutants during production than the traditional counterparts. Soybeans products now are utilized in Ford car in USA[9].

Reuse is common in thrift stores. It is most probably to happen in construction projects by using the entire existing building or some of its components instead of directing them to the waste stream. Recycling means favoring products with recycling content over product with virgin materials. It also means closing the loop to save the natural resources, the energy to process, and the waste associated with production. So the waste will be considered raw materials and feedstock for new products. For example recycling one Aluminum can saves electricity to power a TV or 100 watt light bulb for three hours. Opportunities to recycle abound in construction industry. Fiberboard, millwork, and flooring may contain recycled wood. Partitions, car stops, and decking may contain recycled plastics. Sheeting and insulation may contain recycled cellulose. Floor mats may contain recycled tires. Upholstery, carpet cushion, and insulation may contain recycled textiles. Concrete and masonry may contain fly ash or slag. Steel generally contains recycled content materials[10].

Resource management implies investigating the possibilities that any of the three factors: pollution, depletion, and destruction will take place during any phase of extraction, manufacturing, transportation, and usage.

[9] ibid
[10] ibid

2. Toxicity

It includes contamination and the consequential degradation of the ecosystem. The preliminary measurement of toxicity in the building industry is indoor environmental quality (IEQ) and particularly indoor air quality (IAQ). IAQ is measured in terms of parts per million of a substance relative to the threshold levels that are the points at which risk to human is unacceptable. Contaminants are not natural, they remain in our body and accumulate to shut down our reproduction and mental functions[11].

Materials selection has a significant impact on IAQ. Materials –such as adhesives- may emit volatile organic compounds (VOCs). Maintenance may require the use of products containing VOCs. All surfaces absorb molecules of chemicals or particles in the air and they may reemit into the air. The rougher the surface, the more sorption is possible. Glass and metals sorb relatively low quantities compared to textiles, wood, and paper. The guidelines for assessing the potential for a product to impact the building's IAQ are:

i. If it outgases, then it will outgas forever.
ii. If it is dry packages, it will release its smell when unpackaged.
iii. If it is wet, then it will probably emit VOCs when curing.

Toxicity assessment is not easy. Many high-performance building materials contain synthetic chemicals and have some green

[11] ibid

nich may also be applied to materials is nown as life-cycle assessment. When pplied to the building, the life-cycle pproach seeks to examine all the nvironmental impacts of the building, from he acquisition of the materials, energies, and natural resources to the point when the building has completed its useful life and is demolished[4]. To be sustainable, such as analysis should be quantitative and include: embodied energy; the level of carbon dioxide equivalent and emissions in the production, use, and disposal of the materials, durability, water use, and capacity for biodegradation, recycling or use[5].

IV. Principles of greenness of materials

Building materials could be assessed in respect to the greenness criteria they might have. These criteria could be obtained by answering the following questions:

i. Is it toxic or hazardous?

ii. Is it a local material?

iii. Is it recycled?

iv. Is it energy-intensive to make?

v. Is it reusable?

Form the previous list it is possible to classify the aspects of greenness into three categories: (1) resource management, (2) toxicity, and (3) performance. These categories help quickly assess and compare the greenness of one product relative to another[6].

1. Resource Management

It refers to the effect on the Earth's resources- perpetual (solar, wind, tidal energy), renewable (timber, soil, grasses), and nonrenewable (oil, coal, metals)- due to the acquisition of raw materials and manufacturing. It is not concerned with what we extract but what remains. Resources are considered to be sustainably managed when they are managed for the benefit of the Earth and for the benefit of future generations instead of for maximization of profit. Sustainable resource management favors the concepts of reduce, reuse, recycle, and renew[7].

Common measurements of resource management include recycled content materials (pre and post consumer) and independent environmental certification of sustainability in acquisition or manufacture. Pre consumer recycled materials never reach the market. It is the scrap of manufacturing as in many industries. The more important is the post consumer recycling. It is a better measurement of greenness. It depends on a means for collecting the post consumer materials and channels the materials back to industry or the original manufacturer[8].

One opportunity for reduction of waste is using alternative agricultural products such as soy resins, cork, or straw. They are

[4] Gottfried, D. (1996), Sustainable Building Technical Manual, USA: Green Building Council,

[5] Davison, M. et al. (2000), Green Building Materials Residence. Waterloo University.

[6] Spiegel, R., and Meadows, D. (1999) Green Building Materials: A Guide to Product Selection and Specification, New York: John Wiley & Sons, Inc.

[7] ibid

[8] ibid

rating programs, and environmental nonprofit organizations.

iv. Review submitted information. Some standards for green building materials do not exist and are performance-based not prescriptive-based. The information completeness is based on trial and error mixed with educated professional opinion.

v. Evaluate green materials. It is the most important step. All the information about the building materials options is available. Each option will have a score and the best will be picked. The greenness of material is determined by answering the questions: what is being used? And how well is it being used? Are we using rare resources, renewable or nonrenewable resources? How are we affecting the quality of the resources and their cycles? Consider local, regional, and global implication of choices.

vi. Pick choice. Any choice will have an impact on the environment, affect the energy and water usage, and shape the daily reality of the people. The approach is to do what we can and continue improving. Sustainability is the goal.

Following are the general rules for designing, specifying, and building green:

i. Maximizing the durability

ii. Maximizing the energy efficiency

iii. Maximizing the future recyclability: mechanical fastening is preferred to adhesive/solvent welding

iv. Maximizing the maintenanceability

v. Maximizing the recycled content: close the loop and try not to send any product to the landfill but should be recycled into another useful product.

vi. Maximizing the use of local and regional materials

vii. Minimizing embodied energy: promote the highest and best use of materials to avoid wasting the embodied energy

viii. Minimizing the use of hazardous natural chemicals (Asbestos, Lead, etc.)

ix. Minimizing the use of synthetic chemicals as they should be considered guilty until proven innocent

II. Masonry Works

i. Clay Masonry Units[24]:

Resource management	: Mining of clay, soil, sand, and limestone causes soil erosion, pollution, and loss of habitat. Salvaged units are available in many communities. Brick firing produces fluorine and chlorine emissions. Lightweight cultured stone made from cement and recycled aggregates are appropriate for some uses. Glass block is available with recycled glass content[25]. Select locally produced masonry units to minimize the environmental impacts of transportation of heavy materials.
Toxicity	: Overall, masonry products produce minimal air pollution[26]. Clay masonry is relatively inert. Oil contaminated soil that is free from hazardous contaminants can be used in the production of brick. Bricks do not produce abnormal exposure to radon gas, except in rare situation.
Performance	: Traditional masonry construction provides thermal mass and durable construction. Masonry is reusable and easily recyclable.

ii. Concrete Masonry Units[27]:

Resource management	: Mining of clay, soil, sand, and limestone causes soil erosion, pollution, and loss of habitat. Salvaged units are available in many communities. Industrial waste byproducts can be used as aggregate in concrete blocks. Combustion emissions from mineral process, limestone calcining and cement kiln operation include carbon dioxide dust and hazardous materials.
Toxicity	: Concrete masonry is relatively inert. Some emissions of aromatic hydrocarbon are reported from concrete masonry units.
Performanee	: Traditional masonry construction provides thermal mass and durable construction. When roughly textured, ribbed. or fluted, masonry can help reduce noise. Consider interlocking concrete masonry units for landscape and retaining walls as the units do not require mortar and are easy disassemble and reuse. Masonry is reusable and easily recyclable. Autoclaved aerated concrete is available.

24 Spiegel, R., and Meadows, D. (1999) *Green Building Materials: A Guide to Product Selection and Specification*, New York: John Wiley & Sons, Inc.

25 Gottfried, D. (1996). *Sustainable Building Technical Manual*, USA Green Building Council,

26 ibid

27 Spiegel, R., and Meadows, D. (1999) *Green Building Materials: A Guide to Product Selection and Specification*, New York: John Wiley & Sons, Inc

Performance : Return excess concrete to suppliers and minimize water use to wash equipment. Concrete additives for retardability of concrete setting are so effective that a part can be brought back to the mix plant for reuse in two days.

Recycled aggregate may contain crushed concrete, brick, and other masonry waste; or it may contain crushed glass. Light-weight concrete may contain volcanic materials in place of the usual stone aggregate[20].

iv. Pre-cast Concrete[21]:

Resource management : Pre-cats concrete plants allow greater efficiency and better pollution prevention than site fabricated concrete. Architectural items (planters, bollards,..) made from lightweight concrete and recycled content aggregate are available. The recycled content includes cellulose, fiberglass, polystyrene, and rubber.

Autoclaved Aerated Concrete (AAC) is a lightweight pre-cast concrete prevalent in Asia, Europe and The Middle East. It is made with Portland cement, silica sand, or fly ash, lime, water, and aluminum powder or paste. It contains hydrogen bubbles that expand the mix to five times the normal volume. Then it is cut into blocks or slabs and steam cured in an autoclave.

Toxicity : AAC uses less Portland cement than cast in place and traditional pre-cast concrete. Air pollution emissions from concrete are low[22].

Performance : AAA could be the sole concrete used in the foundations. It has a lesser density but a higher insulation capacity, so reduces heat and energy loss by creating a more efficient building envelope[23]. AAC is light (one fifth the weight of traditional concrete) than normal concrete and can be formed into blocks or panels. AAC has the structural. Fire resistive, and acoustic properties of concrete. It ean be cut with a saw like wood products. AAC is thermally efficient and more dimensionally stable than standard concrete.

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[20] Gottfried. D (1996). *Sustamable Building Technical Manual*, USA Green Building Council.

[21] Spiegel. R., and Meadows. D (1999) *Green Building Materials A Guide to Product Selection and Specification*. New York John Wiley & Sons. Inc

[22] Environmental building news. at http // www.ebuild com/archives/products_reviews

[23] http // www.ebuild com

VII Conclusions and recommendations

The conclusion can summarize the rules of selecting green building materials. The general rules are: maximizing the durability, maximizing the energy efficiency, maximizing the future recycleability, maximizing the maintainability, maximizing the recycled content and elosing the loop, maximizing the use of local and regional materials, minimizing the embodied energy, minimizing the use of hazardous natural chemicals, and minimizing the use of synthetic chemicals.

There are limitations to the sustainability of any construction materials used. For this reason, a primary recommendation is the use of secondary materials such as fly ash, recycled brick and aggregate, and recycled steel in the construction process. This reduces the overall demand for virgin renewable and non-renewable resources.

Construction materials that are more ecologically sustainable are available for use in large scale buildings at a cost equivalent to that of the traditional ones. There are reasonable alternatives for more ecologically sustainable building materials, they require further qualitative and quantitative research before implementation. Therefore a fundamental recommendation is that further research projects should be undertaken on the subject.

VIII Summary

Environmentally friendly products (also called "Green products") look distinctive. Green building materials are green in the way they are manufactured, used, and recycled after use. What is meant here are alternative agricultural, recycled content, nontoxic, and energy efficient products that may display environmental ethics. Prior to the industrial revolution, society met most of their needs with materials from the earth and then returned to the earth after use. Nowadays, many green products are gaining ground in the mainstream. That means they could perform and are cost- competitive.

Principles of assessing the greenness of building materials include: resource management, toxicity, and performance. The assessment should investigate the environmental impacts of the building materials through their whole life-cycles.

The product selection process includes: identifying materials category, identifying green building materials options, gathering technical information, reviewing submitted information for completeness, evaluate materials, and select and document choice.

The conclusion of the paper can summarize the rules of selecting green building materials that are: maximizing the durability, maximizing the energy efficiency, maximizing the future recycleability, maximizing the maintainability, maximizing the recycled content and closing the loop, maximizing the use of local and regional materials, minimizing the embodied energy, minimizing the use of hazardous natural chemicals, and minimizing the use of synthetic chemicals. Finally, the sustainable manners of using concrete different types and masonry units are explained in details within this search paper.

iii. Adobe Masonry Units[28]:

Resource management : Adobe blocks are made from local clays/soils and water and dried in the sun without pollution. Adobe soil is a byproduct of sand and gravel mining. Straw is sometimes added to prevent cracking. To prevent disintegration by moisture and rain adobe is protected by cement plaster and overhangs. It also may be stabilized with asphalt emulsion with water and surfactants.

Toxicity : Limited VOC out gassing is associated with asphalt emulsion.

Performance : Adobe block provides thermal mass. It includes structural bricks, face brick and tiles. It is suitable for wide range of cold and wet climates. An unstablized wall without protection from rain will erode at rate of 1 inch per 20 years. Demolished adobe can be returned to the soil. An early English building technique called Cob Wall uses materials similar to adobe (earth mixed with sand and straw). It requires no farming, no cement or mortar. It can form organic straps.

iv. Rammed Earth[29]:

Resource management : It is a compacted mixture of earth and Portland cement.

Toxicity : Rammed Earth is natural and nontoxic. It is frequently left unfinished on the interior.

Performance : The soil materials are rammed within formwork on site. 8 inches width of mix is compacted into 4 inches of depth in each layer. Walls after curing may be left exposed or plastered. Like adobe, rammed earth structures perform best in sunny elimates. They can withstand water too. The Great Wall of China constructed 200 B.C. is made of rammed earth. About 15% of France's population reside in rammed earth structures. Rammed earth construction provides thermal mass, and is water- and fire-resistant, but it is not appropriate when subject to seismic loads.

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[28] ibid

[29] Spiegel, R., and Meadows, D. (1999) *Green Building Materials. A Guide to Product Selection and Specification*, New York: John Wiley & Sons, Inc

'I. The practical green guide for concrete and masonry works

Applying the above list on concrete and masonry we can reach the practical guide for their works.

.. Concrete Works

. Concrete Accessories and Forms[14]:

Resource management : It includes forms for structural and architectural cast-in-place concrete. Options for permanent formwork include earth forms and insulated stackable forms made of recycled polystyrene pellets and cement. Temporary forms (metal, wood, and corrugated paper forms) are reusable and easily recycled. Specify recycled or sustainably harvested wood.

Toxicity : There are 100% biodegradable, zero VOC from release agents available.

Performance : Permanent insulation formwork conserves energy, reuse temporary forms, reuse and recycle used up formwork.

ii. Concrete Reinforcement[15]:

Resource management : Steel reinforcement typically contains recycled steel. Fibrous reinforcement fabricated from recycled plastic is available. Chairs and bolsters fabricated from recycled plastics are available. Steel reinforcement containing 100% remelt steel is available. Anticorrosion agents such as epoxy coating extend the life of steel reinforcement as they the life of slabs avoiding repair and replacement costs[16].

Toxicity : Steel does not outgas, however the coat of oil found on some steel framing may cause irritation.

Performance : Steel reinforcing may be separated by magnets from concrete aggregate. Separation of plastics may require water to float plastic.

iii. Cast-In-Place Concrete[17]:

Resource management : Mining of aggregate and Portland cement components such as: Lime, Oxides of Calcium Silicon, Aluminum, and Iron) causes soil erosion, pollution, and habitat loss. Where Pozzolanic cement is specified, natural Pozzolans such as Diatomaceous earth, Volcanic ash, and Pumicites may be used. Fly ash may be a substitute for 30% of Portland cement[18]. Specify 20% fly ash or 30% ground granulated blast furnace slag content in cement and concrete.

Toxicity : Air pollution emissions from concrete are low[19]. The production of Portland cement generates large volumes of Co_2 and dust. Concrete is inert when cured. Admixtures curing compounds and sealers may emit VOCs. Specify water-based, zero or low VOC adhesives, sealers, and coatings. Specify temporary ventilation during placing and curing for interior work. Consider future disassembly and possible options for recycling concrete that has encapsulated hazardous materials.

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[14] Spiegel, R., and Meadows, D. (1999) *Green Building Materials: A Guide to Product Selection and Specification*. New York. John Wiley & Sons, Inc.

[15] Ibid

[16] Environmental building news, at http // www.ebuild.com/archives/products_reviews

[17] Spiegel, R., and Meadows, D. (1999) *Green Building Materials. A Guide to Product Selection and Specification*. New York. John Wiley & Sons, Inc.

[18] http:// www dep.state.ct us/wst/recycle/greenconst htm

[19] Environmental building news, at http:// www ebuild com/archives/products_reviews

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