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USING CONCRETE TO COMPLY WITH THE INTERNATIONAL GREEN CONSTRUCTION CODE (IGCC) AND ASHRAE 189.1

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ABSTRACT:

The first green code-intended standard for commercial buildings, *ASHRAE/USGBC/IES Standard 189.1 - High Performance Green Buildings*, was first published in 2009. The *International Green Construction Code (IgCC)* was first published in 2012. ASHRAE 189.1 is a compliance option of the IgCC. This paper provides information on how the attributes of concrete and masonry can be used to comply with the criteria in the IgCC and ASHRAE 189.1. These attributes include heat island mitigation, stormwater management, energy efficiency, acoustical control, low-emitting materials, construction waste, recycled content, regional (indigenous) content, life cycle assessment, and service life.

Keywords: ASHRAE 189.1, concrete, construction waste, green buildings, IgCC, life cycle assessment, masonry, pervious concrete, service life, thermal mass

1. INTRODUCTION

The first green code-intended standard for commercial buildings, *ANSI/ASHRAE/USGBC/IES Standard 189.1-Standard for the Design of High Performance Green Buildings* [1], was first published in 2009 by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The co-sponsors, ASHRAE, the U.S. Green Building Council (USGBC), and the Illuminating Engineering Society (IES), developed the standard over 3.5 years in accordance with the American National Standards Institute (ANSI) consensus process.

The *International Green Construction Code (IgCC)* [2] was first published by the International Code Council in 2012. The co-sponsors are the same as those for ASHRAE 189.1 and, in addition, the American Institute of Architects (AIA) and ASTM International. ASHRAE 189.1 is a compliance option of the IgCC – when complying with the IgCC, the user can comply with either ASHRAE 189.1 or Chapters 2 through 12 of the IgCC. The buildings covered in the scope of ASHRAE 189.1 are all buildings except low-rise residential buildings, and that is the scope of this paper.

Currently, the following jurisdictions in the USA have adopted the code, mostly as a voluntary path for building projects:

- Phoenix, Arizona
- State of Maryland
- State of Rhode Island
- Kayenta Township, Arizona
- Fort Collins, Colorado
- Boynton Beach, Florida
- Keene, New Hampshire
- Richland, Washington
- State of Oregon
- Portions of the state of Florida [3]

Countries, cities, and other international communities are encouraged to adopt of ASHRAE 189.1 or the IgCC in addition to a minimum building code. ASHRAE 189.1 does not need to be used as part of IgCC—universities, corporations, and local and international communities can specify compliance with it. For instance, the U.S. Army announced in October 2010 its adoption of the standard as the core of its Sustainable Design and Development (SDD) Policy for Army Facilities. Further, Leadership in Energy and Environmental Design (LEED) [4] and other rating systems and green standards could choose to use it as a baseline.

This paper provides an overview on how the attributes of concrete and masonry can be used to assist the overall building project in complying with the criteria in the IgCC and ASHRAE 189.1. These attributes include heat island mitigation, stormwater management, energy efficiency, acoustical control, low-emitting materials, construction waste, recycled content, regional (indigenous) content, life cycle assessment, and service life. Actual requirements are contained in ASHRAE

189.1 and the IgCC; only a summary is provided in this paper.

ASHRAE 189.1 and the IgCC are not point or rating systems like LEED; rather, they have minimum requirements. This provides a more direct application for their use and for their adoption into local codes. ASHRAE 189.1 covers topics grouped into these categories:

- Site sustainability
- Water efficiency
- Energy efficiency
- Indoor environmental quality
- Impact of materials and resources
- Construction and plans for operation

The IgCC covers similar topics with similar intent. However, since the two used different development processes, the criteria are different.

To apply ASHRAE 189.1, all mandatory requirements must be met, along with those of either the prescriptive or performance path, where applicable. The prescriptive path specifies a relatively simple method for showing compliance that generally involves little or no calculations; the performance path involves an alternative method typically more complex than the prescriptive path.

The IgCC, also written in mandatory code language, requires compliance with mandatory and prescriptive or performance options, along with a certain number of project electives. The adopting jurisdiction can also choose jurisdictional electives. In codes, standards, and rating systems, multiple options (*e.g.* LEED credits or IgCC project electives) often lead to the selection of the least-expensive compliance requirements, rather than the ones that provide the greatest reduction in environmental impact. ASHRAE 189.1 does not have these options to select, but there is some flexibility in the form of alternative paths and exceptions.

2. SITE SUSTAINABILITY

The use of concrete and masonry can help a project meet the site sustainability requirements of ASHRAE 189.1 and the IgCC through the reduction of heat islands and stormwater management sections.

2.1 Heat Island Mitigation, Site Hardscape

In ASHRAE 189.1 and the IgCC, the heat island effect from non-roof horizontal surfaces is required to be mitigated through the use of shade on 50% of the hardscape or through the use of certain materials as hardscape. This requirement pertains to all climates except cold climates; it applies to Climate Zones 1 through 5, as described in both documents, with less than 4000 Heating Degree Days Base 18°C - HDD18°C (7200 HDD65°F) in ASHRAE 189.1 and Climate Zones 1 through 6 with less than 5000 HDD18°C (9000 HDD65°F) in the IgCC. Paved areas such as roads, parking lots, driveways, patios, plazas, sidewalks, and paths are considered hardscape.

New concrete without added color pigments complies with this requirement without further testing in both documents. A difference in the IgCC (that is not in ASHRAE 189.1) is that the concrete does not need to be new to comply; in ASHRAE 189.1 concrete that is not new needs to be tested. The testing requirements are slightly different for the two documents but the outcomes are similar. In ASHRAE 189.1, hardscape with an initial solar reflectance index (SRI) of at least 29 complies. In the IgCC, hardscape with an initial solar reflectance of at least 0.30 complies. Most ordinary concrete meets these values [5].

The two documents have slightly different requirements for permeable pavement. Permeable concrete pavement (such as pervious concrete, shown in Fig. 1) complies without further testing in the IgCC. In ASHRAE 189.1, open-graded (uniform-sized) aggregate hardscape and open-grid pavers comply without further testing. Permeable pavement and permeable pavers comply with ASHRAE 189.1 and open-graded aggregate, open-grid pavers, and other permeable pavement comply with the IgCC when they have a percolation rate of at least 100 $L/min \cdot m^2$ (2 $gal/min \cdot ft^2$).

2.2 Heat Island Mitigation, Walls

In ASHRAE 189.1, the heat island effect from vertical surfaces is required to be mitigated through the use of shade on 30% of east and west-facing, above-grade walls and retaining walls that are within 6 m (20 ft) of the ground. An example is shown in Fig. 2. In lieu of shade, this requirement is met if at least 75% of the opaque wall surfaces on the east and west facades have an SRI of at least 29. This requirement also pertains to all climates except cold climates: Climate Zones 1 through 4 with more than 3000 HDD18°C (5400 HDD 65°F) on east facades and Climate Zones 1 through 6 with less than 5000 HDD18°C (9000 HDD65°F) on west facades.

The IgCC does not have heat island mitigation requirements for vertical surfaces.

2.3 Stormwater Management

The prescriptive compliance option in ASHRAE 189.1 for stormwater management requires 40% of an entire site area to be pervious. This can be accomplished through vegetation, vegetated (green) roofs, or the use of certain materials. Open-grid pavers comply without further testing. Permeable pavement, permeable pavers, and open-graded aggregate comply when they have a percolation rate of at least 100 L/min·m^2 (2 gal/min·ft^2).

The IgCC has requirements for stormwater management that encourage the same kinds of permeable materials as those listed in ASHRAE 189.1. However, the criteria are performance requirements and do not list materials that comply.

3. ENERGY EFFICIENCY

The energy efficiency of buildings can be met in ASHRAE 189.1 and the IgCC by either prescriptive requirements or performance requirements.

3.1 Prescriptive Requirements

The prescriptive requirements in both documents generally provide for reduced amounts for insulation in mass walls compared to that in wood or metal frame walls due to the energy-savings benefits of thermal mass. ASHRAE 189.1 uses the definition of mass walls in ASHRAE 90.1 [6]: a wall with a heat capacity "exceeding (1) 143 kJ/m^2·K (7 Btu/ft^2·°F) or (2) 102 kJ/m^2·K (5 Btu/ft^2·°F), provided that the wall has a material unit weight not greater than 1920 kg/m^3 (120 lb/ft^3)." ASHRAE 189.1 then provides criteria for assembly types including mass walls in the form of tables.

The IgCC uses the definition of mass walls in the *International Energy Conservation Code* (*IECC*) [7]: "walls weighing at least (1) 35 psf (170 kg/m^2) of wall surface area; or (2) 25 psf (120 kg/m^2) of wall surface area if the material weight is not more than 120 pounds per cubic foot (pcf) (1900 kg/m^3)". This is similar to the definition of mass walls in ASHRAE 189.1, and has the same effect, but is in different units that are considered easier for compliance. The IgCC then requires that the U-factor be reduced by 10% from the requirements in the IECC.

3.2 Performance Requirements

In lieu of the prescriptive compliance option, ASHRAE 189.1 and the IgCC allow a more complex performance compliance option to demonstrate energy efficiency. Using this option, a reference building meeting certain specified requirements, as well as a proposed building, are modeled using energy software that simulates building energy use for every hour for an entire year using average weather data. Metrics based on annual energy use for the proposed building must be less than that for the reference building.

Using the performance path requires an understanding of complex software as well as the required inputs for the building envelope, heating, ventilation, cooling, and lighting. Most simulators use *EnergyPlus* or *DOE2* based simulation programs. Both of these can be used to show the benefits of thermal mass. *EnergyPlus* more accurately simulates thermal mass effects and is more likely to show more energy savings when thermal mass is used than *DOE2* based programs. However, *DOE2* based software programs generally require less time to learn and are easier to use.

Dynamic modeling capabilities are more complicated than steady-state, so EnergyPlus and *DOE2* have default options that allow the input of steady-state R-values or U-factor properties for walls rather than the more complex wall properties required for dynamic analysis. When the familiar steady-state properties are input, the thermal mass effects of the walls or other building envelope components are not accounted for, and this is not readily known by some users.

To activate the dynamic functions of the software that simulate thermal mass, the individual concrete and masonry materials should be defined according to their material properties, such as thickness, thermal conductivity, density, and specific heat (or thermal diffusivity).

4. INDOOR ENVIRONMENTAL QUALITY

4.1 Acoustical Control – Sound Reduction

Concrete roof-ceilings as well as concrete and masonry walls can help meet the interior and exterior acoustical control (sound reduction) requirements in ASHRAE 189.1 based on Sound Transmission Class (STCs).

Wall and roof-ceilings that compose the thermal envelope (exterior) of the building require a composite STC rating of at least 50 or the less common Outdoor-Indoor Sound Transmission (OITC) of at least 40 for these conditions:

- Buildings within 300 m (1000 ft) of expressways
- Buildings within 8 km (5 miles) of airports serving more than 10,000 commercial jets per year
- Where certain sound levels at the property line exceed 65 decibels.

The IgCC does not have a requirement for exterior roof-ceilings and walls.

The acoustical control requirements for interior wall and floor-ceilings separating spaces are slightly different in ASHRAE 189.1 and the IgCC. The spaces are defined using different terminology and the requirements are somewhat different.

Interior wall and floor-ceilings separating specified spaces require a minimum STC in ASHRAE 189.1. These include spaces separating:

- Dwelling units, tenant spaces, classrooms, and other specified spaces where STC must be at least 50
- Hotel rooms, motel rooms, and patient rooms in nursing homes and hospitals where STC must be at least 45

They also include interior wall and roof-ceilings separating classrooms from:

- Rest rooms and showers where the STC must be at least 53
- Music rooms, mechanical rooms, cafeteria, gymnasiums, and indoor swimming pools where the STC must be at least 60

The IgCC has different interior wall and floor-ceiling requirements. These include spaces separating:

- Group A (assembly) and F (factory) occupancies from one another or from Group B (business), I (institutional), M (mercantile), or R (residential) occupancies, where the STC must be at least 60 or the apparent sound transmission class (ASTC) must be at least 55 if field tested
- Group B, I, M, or R occupancies from one another where the STC must be at least 50 or the ASTC must be at least 45 if field tested
- Group R condominium occupancies from one another or from other Group B, I, M, or R occupancies where the STC must be at least 55 or the ASTC must be at least 50 if field tested
- A mechanical or emergency generator equipment room or space from the remainder of the building where the STC must be at least 60

4.2 Low-Emitting Materials

Materials emissions as presented in this section are intended to minimize the potential health effects related to off-gassing of materials in the indoor environment. ASHRAE 189.1 does not have low-emitting material requirements for concrete and masonry. However, it does have requirements for adhesives, sealants, paints, coatings, floor coverings, and other materials that might be applied to concrete and masonry. The IgCC states that concrete, concrete tile, clay pavers, concrete pavers, clay masonry, and concrete masonry comply with the VOC emission requirements if post-manufactured coatings or surface applications have not been applied. Therefore, neither ASHRAE 189.1 nor the IgCC require emissions testing for uncoated concrete and masonry.

In addition, the IgCC has three project electives, one each for flooring, ceiling, and wall materials. One method of obtaining these are if the assembly is constructed of concrete, concrete tile, clay pavers, concrete pavers, clay masonry, and concrete masonry. Once again, post-manufactured coatings or surface applications cannot be applied.

5. IMPACT OF MATERIALS AND RESOUCES

5.1 Minimizing Construction Waste

ASHRAE 189.1 requires that new buildings or sites with less than 5% existing buildings, structures, or hardscape limit the total amount of construction waste. This waste cannot exceed 35 m^3 or 6000 kg per 1000 m^2 (42 yd^2 or 12,000 lbs per 10,000 ft^2) of new building floor area. This applies to all waste regardless of where it is diverted, landfilled, incinerated, or otherwise disposed. Approximately 25% of the non-industrial waste in the USA is from building-related construction and demolition debris [8]. Concrete and masonry that is efficiently designed and delivered to the site minimizes construction waste.

The IgCC does not have a requirement but has a project elective on minimizing construction waste. This limits the amount of construction waste, excluding hardscape, that is allowed in a landfill to 1.8 kg (4 lb) per 0.093 m^2 (1 ft^2) of building area. The requirement for ASHRAE 189.1 is in terms of new floor area whereas the elective in the IgCC is in terms of building area.

5.2 Diverting Construction Waste from Disposal

ASHRAE 189.1 requires that at least 50% of the construction and demolition waste from a project site be diverted from disposal in landfills and from incineration. This diverted waste must be recycled or reused. Calculations are allowed to be done by either weight or volume as long as they are done consistently using the same metric. Hazardous waste is not included in the requirement or calculations. Most concrete and masonry waste in large urban areas in the USA is reused as road base or fill material and therefore counts towards this requirement. Fig. 3 shows demolished concrete being crushed for reuse as fill material on a site.

The IgCC has a similar requirement except it requires that at least 50% of nonhardous construction waste be diverted from disposal. ASHRAE 189.1 has requirements that include diverting demolition waste from landfills whereas the IgCC does not.

The IgCC has a project elective increasing the amount to be diverted by 20%. The IgCC also has jurisdictional options for increasing this to at least 65% or 75%. A jurisdictional option is enacted when a jurisdiction (e.g., a nation, county, or city) mandates the higher requirement when it adopts the IgCC.

5.3 Reduced Impact Materials – Recycled and Regional (Indigenous) Content

The criteria on reduced impact materials in ASHRAE 189.1 can be met by either prescriptive requirements or performance requirements.

The prescriptive requirements in ASHRAE 189.1 can be met by complying with one of the following requirements: recycled content, regional materials content, or biobased content. For concrete and masonry, the focus is on recycled content and regional content. Using recycled content materials reduces the need for mining virgin materials. Using regional materials reduces energy used to transport materials, stimulates the local economy, and can reduce environmental impacts. These impacts are reduced by importing less material from countries with more polluting industries than the home country.

When the recycled content option is selected, at least 10% of the total materials on the project, based on cost, must be have recycled content. This recycled content is composed of post-consumer recycled content (material has made its way to the end of its useful life in the hands of the end consumer) plus one-half of the pre-consumer content (recovered material from an industrial process used by another industrial process).

The recycled content of concrete may be calculated either as a single product or by the separate contributions of the constituent materials: cementitious material, aggregate (sand, gravel, and crushed stone) and water.

The calculation by constituent material for concrete recognizes the benefit of supplementary cementitious materials (SCMs) with recycled content. Although cement is only 7% to 15% of the material in concrete, by weight, it is a fired material with significantly more environmental impacts than sand, gravel, or water. SCMs such as a fly ash, slag cement, and silica fume are recovered from other industrial processes. When used as a replacement for a portion of the cement in concrete, these materials can significantly reduce the environmental impact of concrete.

When the regional content option is selected in ASHRAE 189.1, at least 15% of the total materials on the project, based on cost, must be regionally extracted/harvested/recovered or manufactured within a radius of 800 km (500 miles). This distance is based on shipping by truck. To account for the more efficient methods of transporting by rail, ship, or barge, a factor of 0.25 is applied to those shipping distances.

The IgCC has a similar intent, but different criteria. The IgCC requires that at least 55% of the materials comply at least one of the following: (1.) be used, (2.) have recycled content of at least 25% and be recyclable, or have 50% recycled content, (3.) be recyclable with a minimum recovery rate of 30% or be recyclable through a national closed-loop manufacturer’s take-back program, (4.) be biobased, or (5.) have indigenous (regional) content as described above for ASHRAE 189.1. Calculations can be done based on mass, volume, or cost as long as they are done consistently using the same metric. When a material complies with more than one of the five options, the material content can be multiplied by the number of options for which it complies.

IgCC also has project electives to increase the required amount of materials from 55% to 70 or 85%.

The ASHRAE 189.1 prescriptive requirement can be met using criteria for recycled content, regional materials content, *or* biobased content. The IgCC is different in that it allows the amounts of materials that meet these attributes to be additive in order to meet a total requirement. The IgCC also allows used and recyclable materials to be included in the total requirement; these are not included in ASHRAE 189.1. The required unit of measurement in ASHRAE 189.1 is the cost of the qualifying materials or portions of materials. Mass, volume, or cost of the qualifying material can be used as the metric in the IgCC as long as only one is chosen and used.

5.4 Whole Building Life Cycle Assessment

Both ASHRAE 189.1 and the IgCC allow a whole building life cycle assessment (LCA) to be used instead of the reduced impact prescriptive requirements described above. In ASHRAE 189.1, life cycle assessment is a performance path alternative and can be done instead of meeting the prescriptive option for recycled, regional, or biobased content. These prescriptive measures are single-attribute criteria that are relatively easy to quantify, but have flaws because they only take into account one specific measure. For instance, recycled content does not consider the energy required to recycle old material into a new product.

LCA is considerably more complex, but also more accurate than any single-attribute criteria. However, it is only precise when it considers a complete range of impacts for the life of the building. ASHRAE 189.1 requires the analysis include the impact categories of:

- Land use (or habitat alteration)
- Resource use
- Climate change
- Ozone layer depletion
- Human health effects
- Ecotoxicity
- Smog
- Acidification
- Eutrophication

The performance path requires an LCA on a base building and the proposed project building in accordance with *ISO 14044-2006*, *Environmental Management: Life Cycle Assessment–Requirements and Guidelines* [9].The proposed project building is required to show at least a 5% improvement in two of nine impact categories required for the analysis. An analysis period of at least 75 years is required for most projects, based on the average life of a USA building, according to the Department of Energy (DOE) [10]. An analysis period of at least 25 years is required for industrial buildings and standalone parking structures. A shorter period is allowed for temporary buildings (defined as non-permanent construction buildings, such as sales offices and bunkhouses) and temporary exhibition buildings. A longer time period for an LCA will put more emphasis on energy use and maintenance during the life of the project.

The LCA is not required to include the energy use over the building's life (operational energy), but results are likely to be incorrect without this data. For instance, more insulation or thermal mass saves energy over the long term. However, unless this reduced consumption is noted, only the negative effects of having additional materials are included.

An LCA is a complex process requiring computer software and analysis. After defining the boundary conditions in an LCA, the next step is a lifecycle inventory (LCI). This is an accounting of the materials and energy consumed (*i.e.* inputs), as well as the emissions to air and water and solid wastes (*i.e.* outputs) during the building's life. As shown in Fig. 4, the LCI includes these inputs and outputs from extraction and harvesting of raw materials and fuel sources, through manufacturing and transporting of components, construction, repair and maintenance, replacement, and finally, deconstruction, demolition, recycling, reuse, and disposal. Once the LCI has been calculated, environmental impacts can be calculated using available simulation programs [11].

In the IgCC, similar to ASHRAE 189.1, LCA is allowed as an alternative to the reuse, recycled, recyclable, biobased, or regional content requirements. In the IgCC, the building must show at least a 20% improvement in global warming potential and at least two of the following impact categories:

- Primary energy use
- Acidification potential
- Eutrophication potential
- Ozone depletion potential
- Smog potential

The LCA must include building operational energy and comply with ISO 14044 [9].

ASHRAE 189.1 and the IgCC have somewhat different impact categories, as described above. They also have somewhat different criteria. ASHRAE 189.1 requires at least a 5% improvement in two impact categories. The IgCC requires at least a 20% improvement in global warming potential and in at least two other impact categories.

6. SERVICE LIFE

The plan for operation in ASHRAE 189.1 must include a service-life plan for the structural, building envelope, and hardscape materials. The objective is to make the owner aware of any materials that might be chosen because they are 'greener' or less expensive, but require more maintenance and replacement during the building's service life. A building or component's service life is its expected lifetime, or the acceptable period of use in service, including anticipated maintenance and repairs. Concrete and masonry generally have a relatively long service life.

The service-life plan is based on similar requirements in *CSA S478-95, Guideline on Durability in Buildings* [12]. It requires identification of materials that need to be inspected, repaired, or replaced during the design life of the building—generally at least 50 years. For structural, building envelope, and hardscape materials, one must identify the estimated service life, maintenance frequency, and access for maintenance. The completed service life plan is submitted to the owner at the completion of design.

In the IgCC, a building service-life plan is a project elective. The design life in years for the building is specified in ASHRAE 189.1 whereas in the IgCC it is determined by the building owner or design professional and then reported. The components included in the service plan are similar in ASHRAE 189.1 and the IgCC but stated differently.

The IgCC requires a maintenance, repair, and replacement schedule for structural elements, concealed materials and assemblies, materials and assemblies with a prohibitive or impractical replacement cost, major materials and assemblies that are replaceable, roof coverings, mechanical electrical, and plumbing equipment and systems, and site hardscape. The plan must be included in the construction documents.

7. SUMMARY

This paper provides an overview on how the attributes of concrete and masonry can be used to assist the overall building project in complying with the criteria in the IgCC and ASHRAE 189.1. These attributes include heat island mitigation, stormwater management, energy efficiency, acoustical control, low-emitting materials, construction waste, recycled content, regional (indigenous) content, life cycle assessment, and service life. Actual requirements are in ASHRAE 189.1 and the IgCC; only a summary has been provided here. ASHRAE 189.1 and the IgCC cover similar topics with similar intent. However, since the two used different development processes, the criteria are often somewhat different.

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11. Examples include SimaPro (www.pre.nl) and Gabi (www.gabi-software.com).

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Figure 1 Pervious concrete used for heat island mitigation and stormwater management

Figure 2 Shading building facades for heat island mitigation

Fig. 3 Demolished concrete being crushed for reuse as fill material on a site

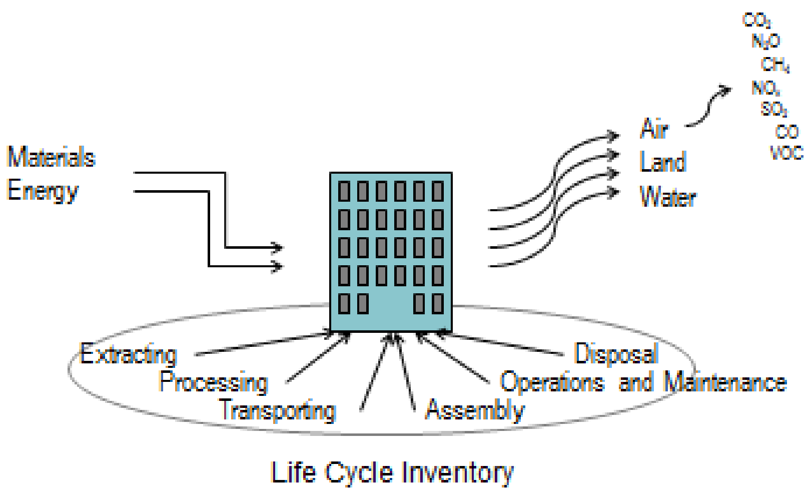

Fig. 4 Inputs and outputs of life cycle inventory