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Environmental life cycle assessment and recycling of ductile iron pipes for water applications

Evaluation du cycle de vie environnemental et recyclage des tuyaux en fonte ductile utilisés pour l'eau

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 5, *Ferrous metal pipes and metallic fittings*, Subcommittee SC 2, *Cast iron pipes, fittings and their joints*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The growing awareness of the importance of environmental protection, and the possible impacts associated with products, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the techniques developed for this purpose is the environmental life cycle assessment (E-LCA).

E-LCA can assist in

— identifying opportunities to improve the environmental performance of products at various points in their life cycle;

— informing decision-makers in industry, government or non-governmental organizations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign);

— the selection of relevant indicators of environmental performance, including measurement techniques;

— marketing (e.g. implementing an ecolabelling scheme, making an environmental claim, or producing an environmental product declaration).

The concept of reference service life (RSL) is defined according to ISO 15686-1:2011 which identifies and establishes general principles for service- life planning and a systematic framework for undertaking service- life planning of a planned construction work throughout its life cycle.

This document is mainly focused on CO_2 emissions. The methods can be applied also to other environmental factors, e.g. other greenhouse gases emissions, natural resources consumption, water consumption.

Environmental life cycle assessment and recycling of ductile iron pipes for water applications

1 Scope

This document specifies the evaluation method of the environmental life cycle assessment (E-LCA) of ductile iron (DI) pipes used for water applications as specified in ISO 2531 and ISO 16631. This evaluation method, applicable to ductile iron pipe products, is based on concepts and methods developed in ISO 14040 and its application guidelines in ISO 14044.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2531:2009, *Ductile iron pipes, fittings, accessories and their joints for water applications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2531 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
environmental life cycle assessment
E-LCA
compilation and evaluation of the inputs, outputs and the potential *environmental impacts* (3.2) of a product system

Note 1 to entry: Environmental life cycle assessment and environmental life cycle analysis are synonymous.

[SOURCE: ISO 14040:2006, 3.2, modified — The term has been changed from "life cycle assessment" to "environmental life cycle assessment"; "throughout its life cycle" at the end of the definition has been removed. Note 1 to entry has been added.]

3.2
environmental impact
change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services

[SOURCE: ISO 14001:2015, 3.2.4, modified — "environmental aspects" has been replaced by "activities, products or services".]

3.3
CO_2 emissions
release of equivalent CO_2 as greenhouse gases into the atmosphere over a specified area and period of time

3.4
service life
period of time after installation during which a facility or its component parts meet or exceed the performance requirements

[SOURCE: ISO 15686-1:2011, 3.25]

3.5
functional unit
quantified performance of a product system for use as a reference unit

[SOURCE: ISO 14040:2006, 3.20]

3.6
reference service life
RSL
service life (3.4) of a product, component, assembly or pipeline which is known to be expected under a particular set, i.e. a reference set, of *in-use conditions* (3.7) and which can form the basis for estimating the service life under other in-use conditions

[SOURCE: ISO 15686-1:2011, 3.22, modified — "system" has been replaced by "pipeline".]

3.7
in-use condition
any circumstance that can impact on the performance of a pipeline, or a part thereof, under normal use

[SOURCE: ISO 15686-1:2011, 3.10, modified — "a building or a constructed asset" has been replaced by "a pipeline".]

4 Basic concept of environmental life cycle assessment (E-LCA)

4.1 General

Studies on environmental impacts are important for utility decision-makers as they seek to balance budget concerns over immediate and long-term needs across acquisition, operation and maintenance, and planned end-of-life. For authorities and engineers designing pipeline systems, E-LCA serves as a tool to study various scenarios to determine the right solution for site-specific conditions and community values, as well as provide the necessary data to support those decisions.

4.2 Definition of environmental life cycle assessment (E-LCA)

E-LCA is a technique used to assess environmental impacts through all the stages of product and service life. The environmental impact associated with the consumption of natural resources or energy and waste disposal can be quantitatively estimated as the amount of CO_2 emissions.

Total CO_2 emissions is calculated using Formula (1) as a total amount of CO_2 emissions through all life cycle stages such as acquisition stage, operation stage, maintenance stage and end-of-life stage.

$$E_T = E_A + E_O + E_M + E_E \quad (1)$$

where

E_T is the total CO_2 emissions through all life cycle stages;

E_A is the CO_2 emissions at acquisition stage;

E_O is the CO_2 emissions at operation stage;

E_M is the CO_2 emissions at maintenance stage;

E_E is the CO_2 emissions at end-of-life stage.

4.3 Calculation method of CO_2 emissions

The total amount of CO_2 emissions is calculated using Formulae (2) to (4) by totalizing all the CO_2 emissions in a period of analysis.

Case 1: $t_n < t_m$

$$E_T = E_A + \sum_{t=1}^{t_n}(E_{O,t} + E_{M,t}) \quad (2)$$

Case 2: $t_n = t_m$

$$E_T = E_A + \sum_{t=1}^{t_n}(E_{O,t} + E_{M,t}) + E_E \quad (3)$$

Case 3: $t_m < t_n < 2 \times t_m$

$$E_T = 2 \times E_A + \sum_{t=1}^{t_n}(E_{O,t} + E_{M,t}) + E_E \quad (4)$$

where

E_T is the total CO_2 emissions;

t is the time in years;

t_n is the period of analysis;

t_m is the service life;

E_A is the CO_2 emissions at acquisition stage;

$E_{O,t}$ is the CO_2 emissions at operation stage in the t^{th} year;

$E_{M,t}$ is the CO_2 emissions at maintenance stage in the t^{th} year;

E_E is the CO_2 emissions at end-of-life stage.

4.4 Other impacts

Environmental impacts can also be evaluated in other categories which are listed below.

— impact on the environment:

  — climate change;

  — air, water and soil pollution;

  — ozone depletion;

  — eutrophication;

  — acidification;

  - reduction of biological diversity;
- impact on human health:
  - hazardous substance emissions;
  - smog formation;
- impact on natural resource consumption:
  - depletion of resources.

5 Breakdown of CO_2 emissions

5.1 CO_2 emissions at acquisition stage

CO_2 emissions at acquisition stage is calculated using Formula (5) as a total of CO_2 emissions with pipe manufacture, construction material production, construction machine operation, transportation and regeneration treatment of excavated soil.

$$E_{A} = E_{AP} + E_{AC} + E_{AO} + E_{AT} + E_{AR} \quad (5)$$

where

E_{A} is the CO_2 emissions at acquisition stage;

E_{AP} is the CO_2 emissions with pipe manufacture (e.g. raw material procurement, transportation to the factory, manufacturing);

E_{AC} is the CO_2 emissions with construction material production (e.g. asphalt pavement materials, road bedding materials, sand);

E_{AO} is the CO_2 emissions with construction machine operation for pipe laying work (e.g. installation of pipes and valves by crane, crush and loading of existing pavement by backhoe, excavation and loading of soil by backhoe, backfilling by backhoe, compaction by tamper, road bedding by tamper or vibratory roller, asphalt paving work by vibratory roller or vibratory compactor);

E_{AT} is the CO_2 emissions with transportation of construction materials, construction machines, excavated soil, ground-improved soil and construction waste;

E_{AR} is the CO_2 emissions with regeneration treatment of excavated soil.

NOTE The calculation methodology for CO_2 emissions with provision for scrap recycling in ductile iron pipe production is given in Annex A.

5.2 CO_2 emissions at operation stage

Annual CO_2 emissions at operation stage is calculated using Formula (6) as a total of CO_2 emissions with pump operation. Calculation method of CO_2 emissions with pump operation is given in Annex B.

$$E_{O,t} = E_{OP,t} \quad (6)$$

where

$E_{O,t}$ is the CO_2 emissions at operation stage in the t^{th} year;

$E_{OP,t}$ is the CO_2 emissions with pump operation in the t^{th} year.

Annex C gives information about the general relative high proportion of CO_2 emissions at operation stage.

5.3 CO_2 emissions at maintenance stage

Annual CO_2 emissions at maintenance stage is calculated using Formula (7) as a total of CO_2 emissions due to leakage, during machine operation for maintenance, production of restoration materials and during machine operation for restoration.

$$E_{\mathrm{M},t} = E_{\mathrm{ML},t} + E_{\mathrm{MM},t} + E_{\mathrm{MP},t} + E_{\mathrm{MR},t} \tag{7}$$

where

$E_{\mathrm{M},t}$ is the CO_2 emissions at maintenance stage in the t^{th} year;

$E_{\mathrm{ML},t}$ is the CO_2 emissions with leakage in the t^{th} year;

$E_{\mathrm{MM},t}$ is the CO_2 emissions with machine operation for maintenance (e.g. inspection, drainage, washing) in the t^{th} year;

$E_{\mathrm{MP},t}$ is the CO_2 emissions with production of restoration materials in the t^{th} year;

$E_{\mathrm{MR},t}$ is the CO_2 emissions with machine operation for restoration work in the t^{th} year.

5.4 CO_2 emissions at end-of-life stage

CO_2 emissions at end-of-life stage is calculated using Formula (8) as a total of CO_2 emissions with machine operation for existing pipeline dismantling, construction waste disposal, transportation of construction materials and reducing waste by recycling.

$$E_{\mathrm{E}} = E_{\mathrm{EM}} + E_{\mathrm{EC}} + E_{\mathrm{ET}} - E_{\mathrm{ER}} \tag{8}$$

where

E_{E} is the CO_2 emissions at end-of-life stage;

E_{EM} is the CO_2 emissions with machine operation for existing pipeline dismantling;

E_{EC} is the CO_2 emissions with construction waste disposal;

E_{ET} is the CO_2 emissions with transportation of construction materials, construction machines, excavated soil and construction wastes;

E_{ER} is the decrease of CO_2 emissions with recycling of excavated pipes as raw materials.

Material recovery is considered to be applicable only to ductile iron pipes.

6 Key drivers for environmental impact reduction

6.1 Durability

6.1.1 Reference service life (RSL) of DI pipes

RSL is dependent on the properties of DI pipes and on the reference in-use conditions. It takes into account the components of a DI pipe that consists of pipe and fittings material, linings and coatings and assembling accessories.

