Chapter 02

Eco-materials

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Introduction

WHAT ARE ECO-MATERIALS?

DÉFINITION

ECO-MATERIALS, SHORT FOR ECOLOGICAL MATERIALS, REFER TO SUBSTANCES AND PRODUCTS DESIGNED AND PRODUCED WITH A FOCUS ON ENVIRONMENTAL SUSTAINABILITY (الإستدامة).

WHAT IS THE GOAL?

AIM

THE GOAL IS TO PROMOTE ECO-FRIENDLY PRACTICES AND CONTRIBUTE TO A MORE SUSTAINABLE (مستدام) AND RESPONSIBLE APPROACH TO RESOURCE UTILIZATION IN VARIOUS INDUSTRIES.

IN OTHER WORDS

- Eco-materials:
  - designed for environmental sustainability,
  - prioritize :
    - renewable resources,
    - recyclability,
    - and low environmental impact.
- They focus on :
  - minimizing resource consumption
  - and pollution,

- They aim to :

  create a more harmonious relationship between human activities and the environment.

- Industries increasingly embrace eco-materials as a strategic move toward responsible and ethical practices. From recycled metals to innovative bioplastics,

Can we get a list of Eco-materials?

Examples :

i. **Bamboo:** A rapidly renewable resource used for flooring, furniture, and even as a construction material.

ii. **Recycled Steel:** Steel made from recycled materials reduces the environmental impact associated with mining and manufacturing.

iii. **Recycled Glass:** Glass can be recycled repeatedly, making it an eco-friendly option for various products.

iv. **Cork:** Harvested from the bark of cork oak trees without harming the tree, cork is used for flooring, insulation, and other applications.

v. **Reclaimed Wood:** Salvaged from old buildings or structures, providing a sustainable alternative to new timber (الأخشاب).

vi. **Recycled Plastic:** Repurposing post-consumer or post-industrial plastic waste into building materials, such as composite decking or insulation.

vii. **Organic Cotton:** Grown without synthetic pesticides or fertilizers, organic cotton is a more environmentally friendly option for textiles.

viii. **Natural Stone:**

- Eco-materials contribute to a more sustainable (maintainable, Durable , مستدام) and resilient (resistant) future. The adoption of eco-materials reflects a crucial step in modifying the environmental impact of production and consumption.

- Eco-materials often involve :
  - renewable resources,
  - reduced energy consumption,
  - and environmentally friendly manufacturing processes.

1. Bioclimatic design

Known as what also?

Other Name

- Bioclimatic design :
  - climatic architecture
  - or environmental design

What is it?

It is an approach to architectural and urban planning that takes into account local climate conditions to create buildings and spaces that are well-adapted to their natural environment.

What is its goal?

The goal of bioclimatic design is to :

- optimize energy efficiency,
- enhance comfort,
- and minimize the environmental impact of structures.

What include key principles of bioclimatic design?

1. Passive Solar Design:
2. Natural Ventilation:
3. Insulation and Thermal Inertia:
4. Water Conservation:
5. Material Selection:
6. Adaptation to Climate Change:

2. Progressive integration of new materials in construction

Here are several trends (tendances) and examples of new materials making inroads in the construction industry:

1. **High-Performance Concrete ;**
2. **Cross-Laminated Timber (CLT) ;**
3. **3D-Printed Construction Materials ;**
4. **Graphene ;**
5. **Transparent Wood ;**
6. **Recycled Plastic Bricks ;**
7. **Smart Materials ;**
8. **Carbon Fiber Reinforcement ;**
9. **Biosynthetic Materials ;**
10. **Photovoltaic (PV) Integrated Materials ;**
11. **Nano-engineered Materials ;**
12. **Flexible and Responsive Materials ;**
13. **Recyclable Building Materials ;**
14. **Thermochromic Materials ;**

3. Examples of new metallurgical materials making inroads in the construction industry

Advancements in metallurgical science have led to the development and adoption of new materials in the construction industry. These materials offer improved properties such as strength, durability, and corrosion resistance.

1. High-Performance Steel Alloys (Alliages d'acier à haute performance)

    - Advanced High-Strength Steels (AHSS):

      These steels exhibit high strength and improved formability, making them suitable for lightweight construction and structural components in buildings and bridges.

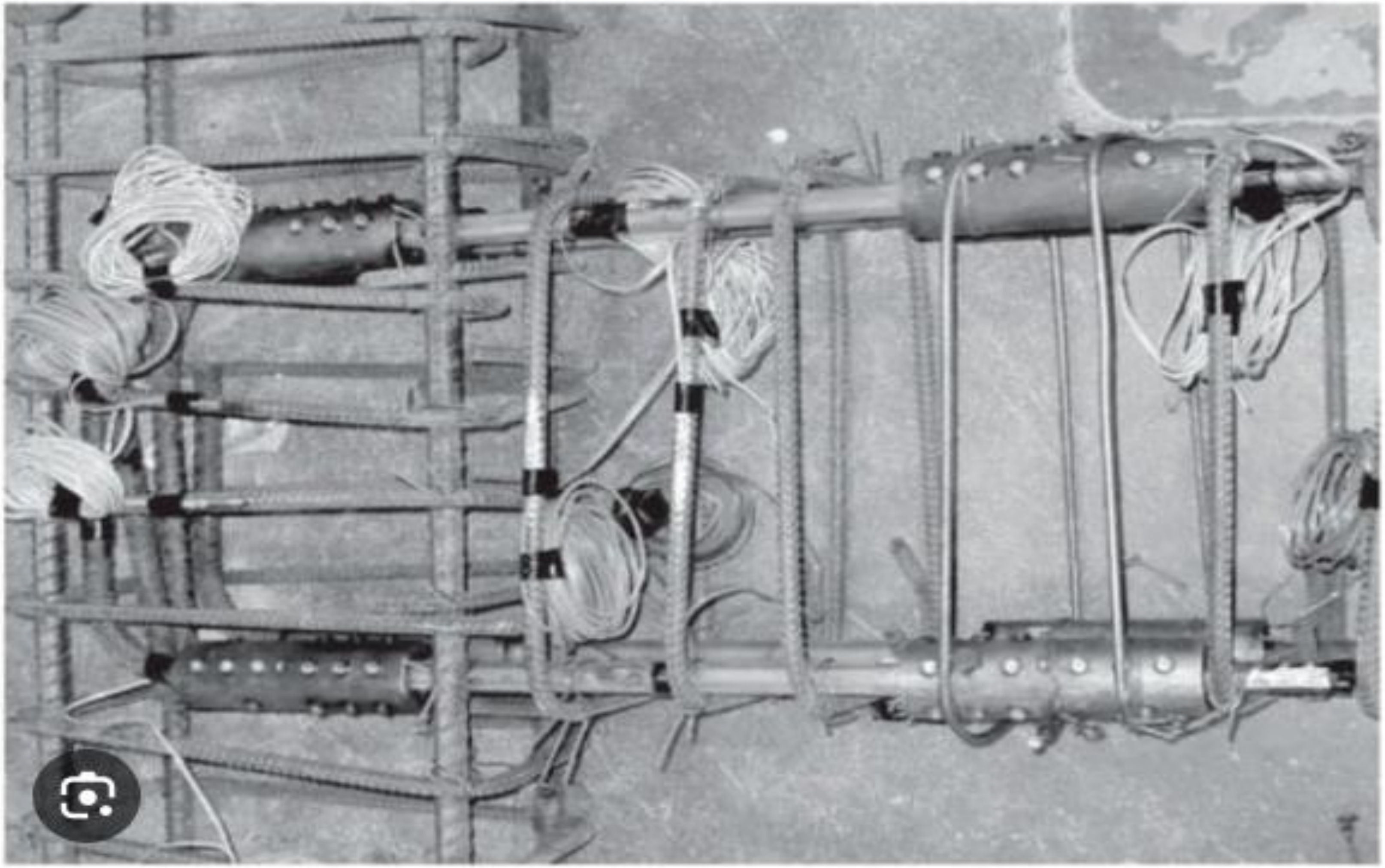
2. Weathering Steel (Corten Steel) (Acier résistant aux intempéries (acier Corten)

- This type of steel develops a protective rust-like appearance when exposed to the weather. It is often used in outdoor structures and facades, offering both aesthetic appeal and corrosion resistance.

V

1. Titanium Alloys:

- Titanium's high strength-to-weight ratio, corrosion resistance, and durability make it suitable for various construction applications, particularly in environments where corrosion is a concern.



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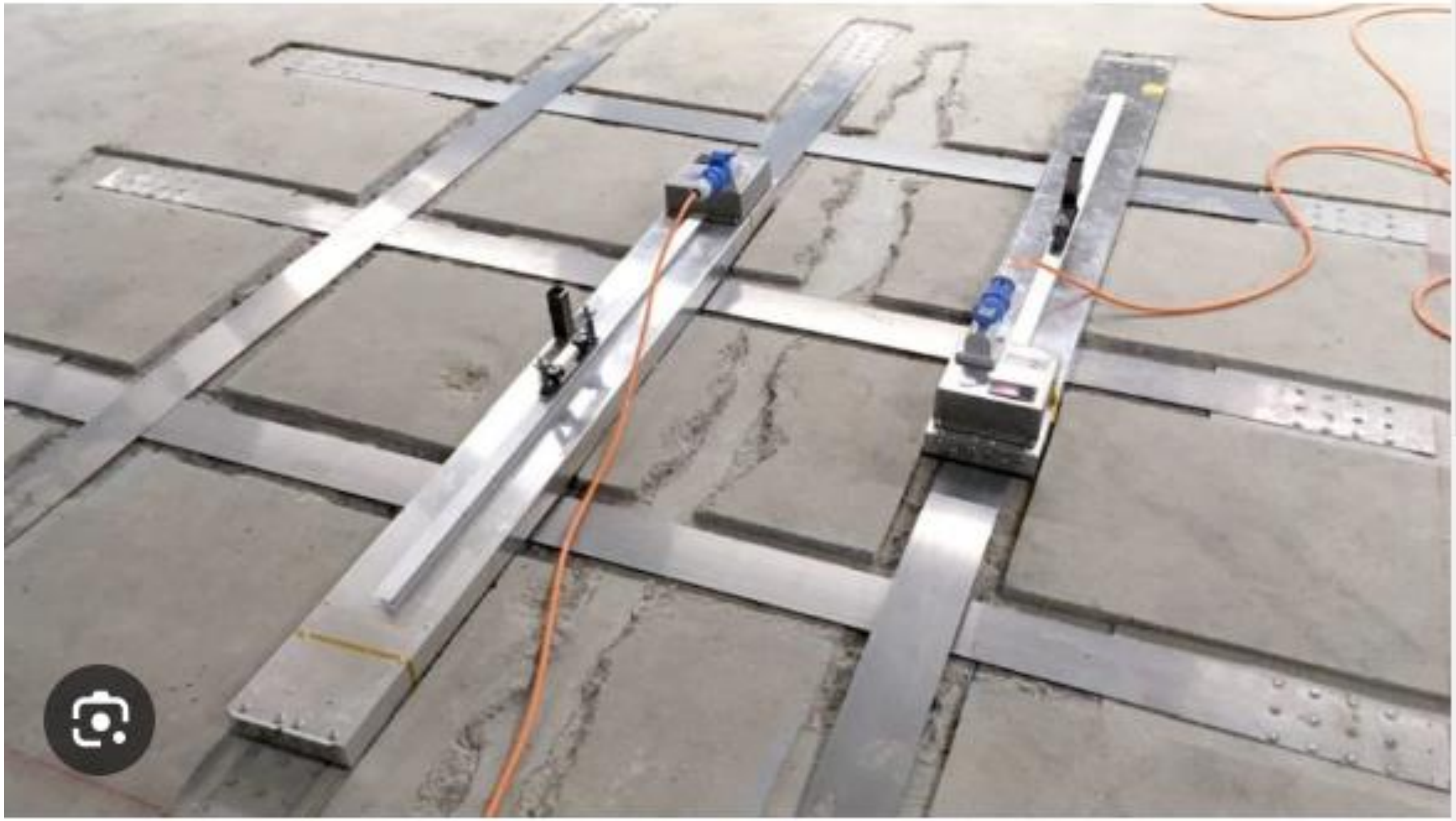
2.Shape Memory Alloys (SMAs):

- SMAs, such as nickel-titanium (Nitinol), have the ability to return to a predetermined shape after deformation. They find applications in seismic-resistant structures and self-healing materials.



Memory steel—a new material for the strengthening of buildings

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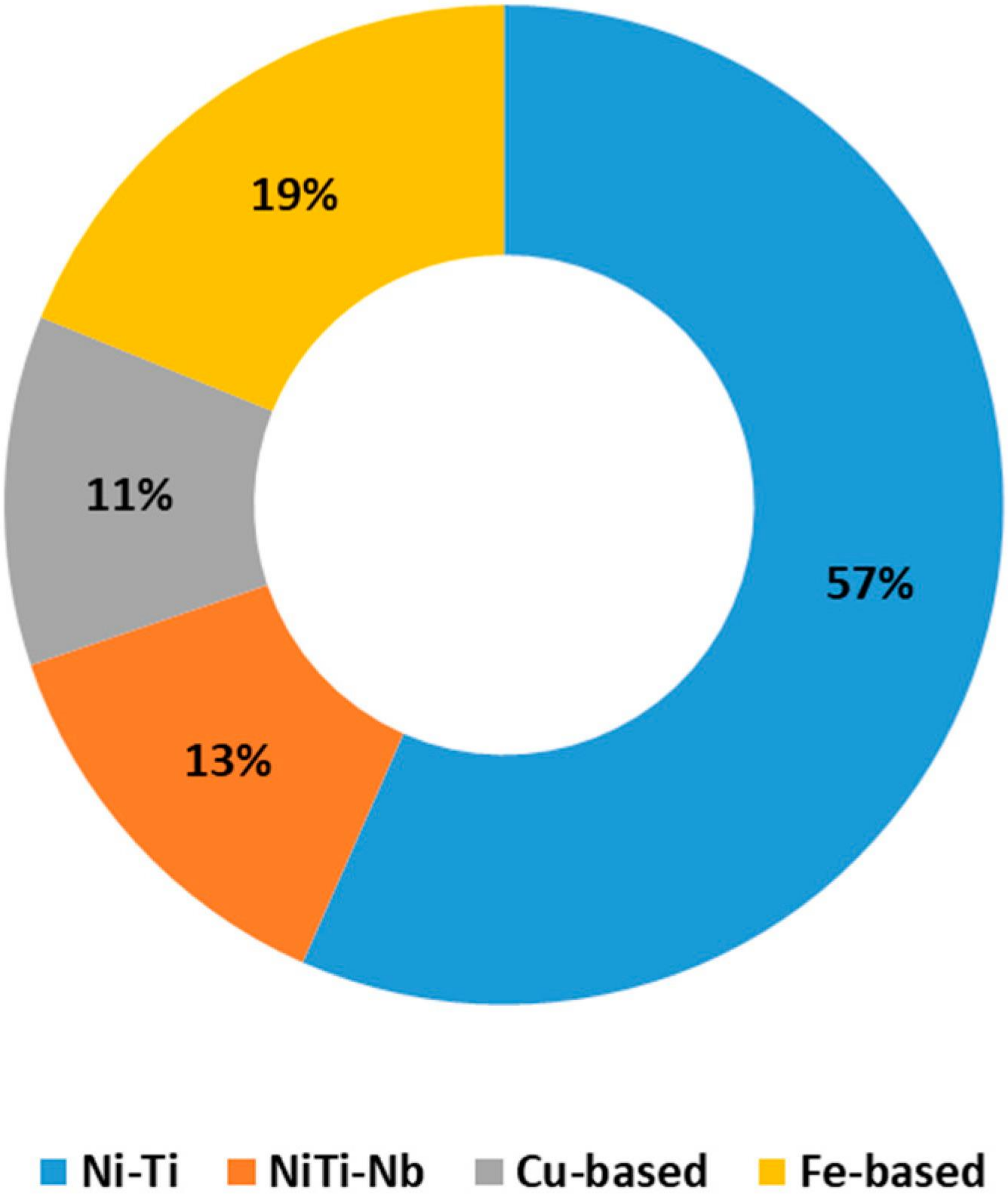
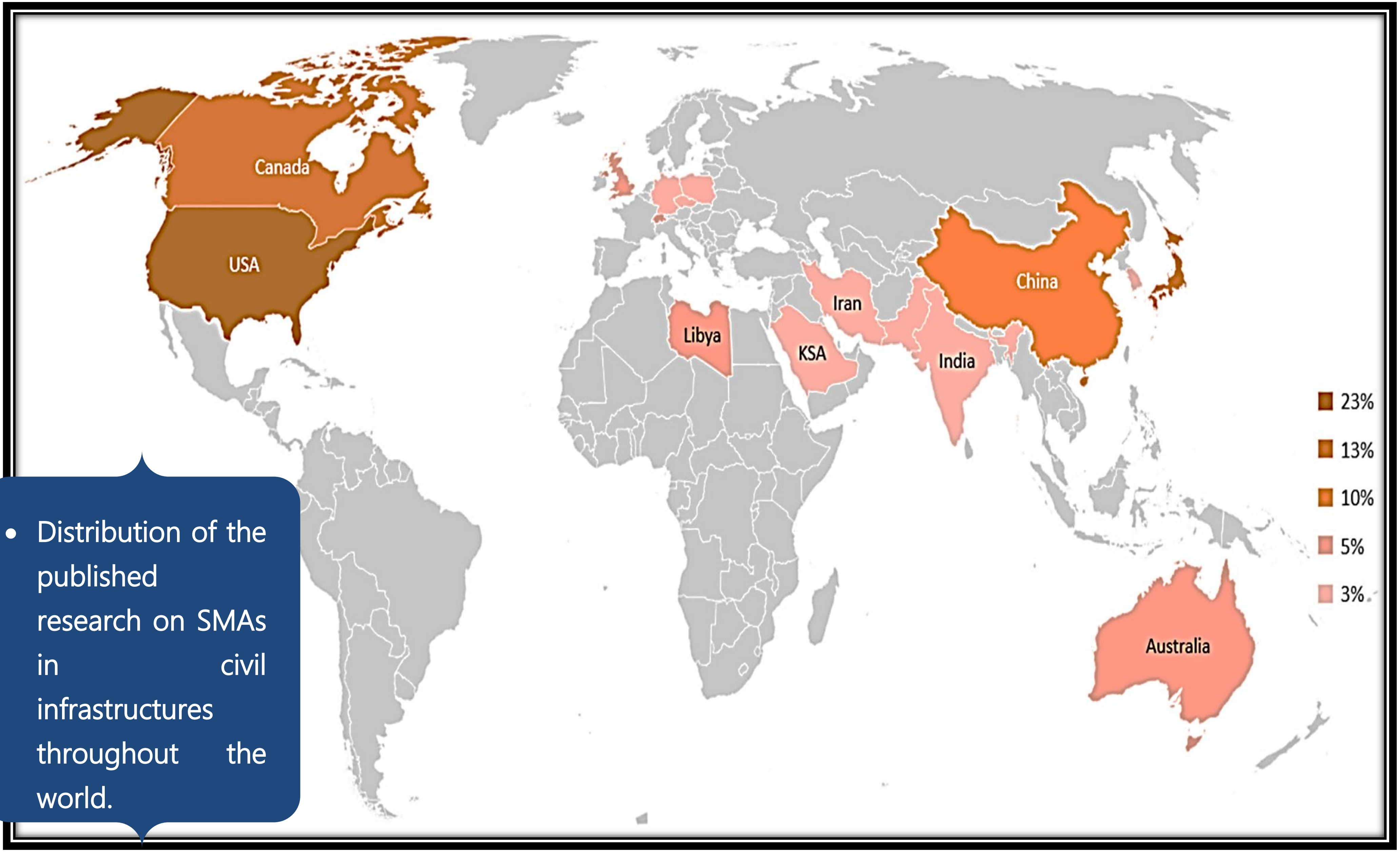
Figure 17. (**a**) As-received SMA; (**b**) SMA in the coupled measurement cell, 70 days; (**c**) steel before immersion in the solution; (**d**) steel specimen in the steel measurement cell, 70 days; (**e**) steel specimen in the coupled measurement cell, 70 days. Reprinted from [62], with permission from American Society of Civil Engineers.

(a) (b) (c) (d) (e)

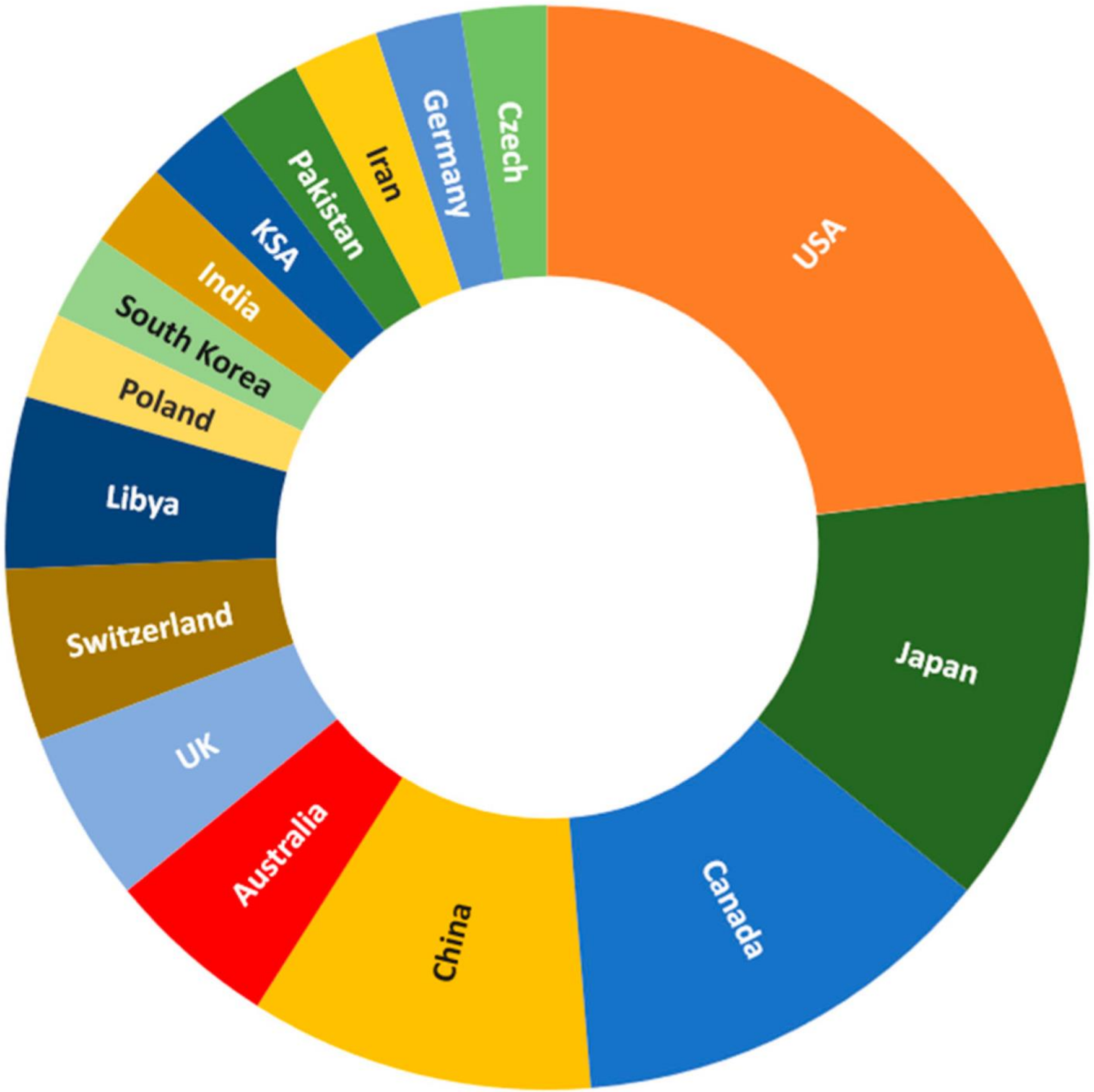


Distribution of the published research in civil engineering sorted by SMA type

https://www.mdpi.com/materials/materials-16-04333/article_deploy/html/images/materials-16-04333-g008-550.jpg



- Distribution of the published research on SMAs in civil infrastructures throughout the world.



- Percentage distribution of the published research on SMAs in civil infrastructures throughout the world.

3. Magnesium Alloys:

4. Aluminum Alloys:

5. Metal Matrix Composites (MMC):

6. High-Entropy Alloys (HEAs):

7. Reinforced Steel with Carbon Nanotubes:

8. Smart Alloys:

9. Metal Foam:

10. Galvanized Steel with Advanced Coatings:

The use of these metallurgical materials in construction reflects ongoing efforts to optimize the performance, sustainability, and longevity of structures. As research and development in metallurgy continue, we can expect further innovations that may revolutionize the construction industry.

4. Reducing CO2 emissions from concrete

i. Introduction

- The cement industry is a major contributor to carbon dioxide (CO2) emissions globally (dans le monde), stemming from (provennant de)the chemical processes involved (impliqué) in cement production.
- Strategies involve using
  - alternative materials,
  - enhancing energy efficiency,
  - adopting carbon capture and storage,
  - and developing low-carbon cement formulations.

ii. Primary sources of CO_2 emissions in the cement

1) Calcination of Limestone ($CaCO_3$)
2) Clinker Formation
3) Fuel Combustion
4) Electricity Consumption

iii. Procedures to reduce CO_2 cement emissions

1. Use Alternative Materials;
2. Blended Cements
3. Energy Efficiency
4. Carbon Capture and Storage (CCS)
5. Renewable Energy Sources
6. Process Optimization
7. Carbon Offsetting
8. Product Innovation
9. Government Regulations and Incentives
10. Life Cycle Assessment (LCA)

1. Use Alternative Materials
    - Substituting some of the traditional clinker with industrial by-products like fly ash or slag (cendre volante et laitier)can reduce the overall carbon footprint of cement.
    - Calcined Clays (Argiles calcinées): Incorporating calcined clays as a supplementary cementitious material can also reduce the need for clinker.
2. Blended Cements(ciment mélangé);

   Use blended cements that combine Portland cement with supplementary cementitious materials. This reduces the reliance on clinker, thereby lowering CO_2 emissions.

3. Energy Efficiency;

   - Implement energy-efficient technologies in cement kilns, such as high-efficiency preheaters and precalciners, which can reduce energy consumption and, consequently, CO_2 emissions.

   - Use alternative fuels like biomass, municipal solid waste, or other low-carbon alternatives instead of traditional fossil fuels in the cement kiln.

4. Carbon Capture and Storage (CCS);

   Implement carbon capture and storage technologies to capture CO_2 emissions before they are released into the atmosphere. This can involve capturing emissions directly from the cement kiln or from the flue gases.

5. Renewable Energy Sources

Power cement plants (alimenter) using renewable energy sources like solar, wind, or hydropower to reduce the carbon intensity of electricity consumption.

6. Process Optimization;

Optimize the cement manufacturing process to reduce energy consumption and emissions. This includes better control of the kiln operation, improved fuel and raw material efficiency, and the use of advanced process control technologies.

7. Carbon Offsetting (Compensation)

Invest in projects that offset carbon emissions, such as reforestation initiatives or other carbon sequestration methods, to compensate for the emissions produced during cement manufacturing.

8. Product Innovation

Develop and promote low-carbon or carbon-neutral cements that have lower environmental impacts compared to traditional Portland cement.

9. Government Regulations and Incentives

Governments can play a crucial role in reducing CO2 emissions by implementing and enforcing regulations that incentivize (motive) the adoption of cleaner technologies and practices in the cement industry.