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Citation for the original published paper (version of record):
Adl-Zarrabi, B. (2017). What is 'Infrastructure Physics'?. Energy Procedia, 132: 520-524.
http://dx.doi.org/10.1016/j.egypro.2017.09.707

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 520–524

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

What is 'Infrastructure Physics'?

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Abstract

Since 2014, the research group 'Infrastructure Physics' sits at the department of Civil and Environmental Engineering, Chalmers University of Technology. A number of researchers wonder 'What is infrastructure physics?' The aim of the paper is to explain and clarify the research field 'infrastructure physics' and its system boundary with other close research fields, such as building physics. Furthermore, some ongoing research projects will be presented briefly. Infrastructure consists of the basic physical systems of a society e.g. transportation, communication, sewage, water and electric systems. Physical infrastructure elements are always exposed to outdoor climate e.g. solar radiation, rain, driving rain, wind, and moisture and temperature variations. The harsh environment around the infrastructure causes different types of destructions that can reduce the function ability in the short time perspective and also reduce the service life time of an infrastructure. Furthermore, extreme weather conditions may cause undesired service interruptions of a system e.g. traffic stop due to flooding. Generally, infrastructure involves a heavy investment for the society which needs also maintenance under long period of time. In other to make the investment more efficient, it is possible to use our infrastructure for other proposes in addition to the initial proposes. For instance, energy harvesting in the vicinity of transport infrastructure. 'Infrastructure physics' deals with physics behind the phenomena related to physical behaviour of the materials, components and systems involved in infrastructure, in their specific environmental condition (underground, subsea, surface) in order to increase their accessibility and efficiency.

Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: Infrastructure physics; ice-free roads; district heating network; non-destructive method; hybrid insulation

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1. Introduction

Infrastructure owners, generally public organizations, in many developed countries, report infrastructure aging, infrastructure failing and that funding has been insufficient to repair and replace them. In urban areas the problem is particularly more severe due to the growing populations that stress society's support systems, among them physical infrastructures. Furthermore, the concept of 'smart city systems' is more and more discussed among international researchers and policy makers. Even if there is still confusion about what a smart city is, smart infrastructure is an essential part of the forthcoming smart cities e.g. new mobility modes require new type of infrastructure. Finally, climate change/global warming should be treated urgently thus the existing and forthcoming infrastructure should be climate neutral. It should also be noted that in many parts of the world, fundamental infrastructure is yet to be in place.

The complex and multidisciplinary picture described above indicates that engineers and researchers dealing with infrastructure under the 21st century, face difficult challenges. They should adopt their solution for fundamental infrastructure to urbanization, digitalization, modernization and threat of climate change. Furthermore, the solutions should be sustainable and proper attention should be given to environmental issues and energy-use. Finally, the solutions should be economically feasible.

Handling a multidisciplinary challenge needs firstly competence in each discipline and secondly competence over the borderline of each discipline e.g. the borderline between structural and nonstructural performance of an infrastructure. The aim of this paper is to define the research field 'Infrastructure physics' and describe how 'Infrastructure physics' complements and supports the field of infrastructure engineering.

2. Definitions/ classifications/limitations

Configuration of the research area 'Infrastructure Physics' needs description of the vision, aim, road map, classification of different types of infrastructure and declaration of some definitions and limitations.

- *Vision:* the vision of the 'infrastructure physics' is 'Forever accessible infrastructure'.

- *Aim*: promoting and being actively involved in research, development and innovations related to physical characteristics of the infrastructure in all stage of its lifetime i.e. design, production, operation and maintenance.

- *Definition of physical infrastructure*: The physical infrastructure can be defined as 'the physical components of interrelated systems providing services essential to enable, sustain, or enhance societal living conditions. The physical infrastructure typically conclude technical structures such as transport infrastructure (road and rail networks, bridges, tunnels), water supply network, heating and cooling supply network, sewers network and, electrical and telecommunication grids.

- *Classification of physical infrastructure*: The physical infrastructure can be divided into two main categories namely surface infrastructure and underground infrastructure. The surface infrastructure includes transport infrastructure, masts for electrical and communication infrastructure, harbours, bus and train terminals and airports. The underground infrastructure includes piping network for water-, heat- and natural gas supply, electrical and communication cables, tunnels that include also subway train network.

- *Roadmap*: In order to plan a roadmap for a number of infrastructure network with different functionalities, it is necessary to find out the common denominator and the major differences.

  Denominator: some major common denominators for all types of physical infrastructure are: heavy initial investment, operation and maintenance costs, length of the infrastructure and their exposure to outdoor climate. The common demands for the physical infrastructure are: accessibility, long-term service time, cost efficiency and sustainability.

Differences: the major difference between the main categories are the environmental conditions that they are subjected to. The surface infrastructure is exposed to atmospheric parameters such as solar radiation, rain, wind as well as moisture and temperature variations. However, underground infrastructure, depending on the buried depth, experiences temperature and moisture in the soil or surrounding materials. Furthermore, another important difference is that it is very difficult to monitor the status of buried infrastructure in comparison with the surface infrastructure.

Combining the common denominators and differences, our vision and aim, the road map can be described as follows: '*The physical behavior of 'forever accessible infrastructure' needs to be monitored/assessed continuously in order to minimize disruption. The data gathered by continuously monitoring should be used for forecasting any forthcoming disruptions. Thus, new and innovative monitoring/measuring and assessment methods and forecasting tools should be developed. Furthermore, the parameters that create a disruption should be identified and treated by innovative measures i.e. systems, tools, structures, components and materials.*'

- *Limitation*: Structural performance of a physical infrastructure will not be covered. However, thermal- and moisture-induced stress is included. Furthermore, cost- and lifecycle analysis will not be treated.

It is the first try for configuration of the research field 'Infrastructure Physics' thus in coming years all described parameters can/will be refined or modified.

3. Is there overlapping with other research fields?

'Infrastructure physics' covers non-structural performance of infrastructure and particularly encompasses the response of infrastructure to their environmental/climate condition thus, heat, air, moisture transfer will be of major importance. The instantaneous reaction could be that it is what a researcher in 'Building Physics' research field is dealing with. It is true when comparing the physical phenomena however, infrastructure is not a part of buildings. Furthermore, if we are just concerned about the physical phenomena involving heat, air, moisture transfer then, indoor climate of a car, cooling car engine, cooling of nuclear plants, etc. are also a part of the research field 'Building Physics'.

The closest overlap with building physicians occurs when 'Infrastructure physics' researcher deals with bus/train terminals and airports. This overlap can be used by researchers from both groups in order to bring more attention to buildings in connection with infrastructures.

The physical infrastructures are exposed to outdoor climate. The research area 'infrastructure physics' treats the influence of outdoor climate in the short and long term performance of physical infrastructure.

4. Ongoing projects

In this section three ongoing projects will be described briefly. The selected projects are status assessment of district heating pipes, hybrid insulation of district heating pipes and ice-free roads. The results of these projects were presented in scientific conferences and journal papers.

4.1. Ice-free roads and bridges

Winter conditions on roads are a challenge for road administrators in cold climates and with increased public demands on safety, winter maintenance activities will increase. The most common winter maintenance activity in Scandinavia is de-icing, which is performed when there is a risk for ice formation on the road surface. Commonly a truck is utilized for spreading freeze point depressant, like salt, on the pavement. This method has been questioned for a number of reasons e.g. salts have negative effects on the local environment.

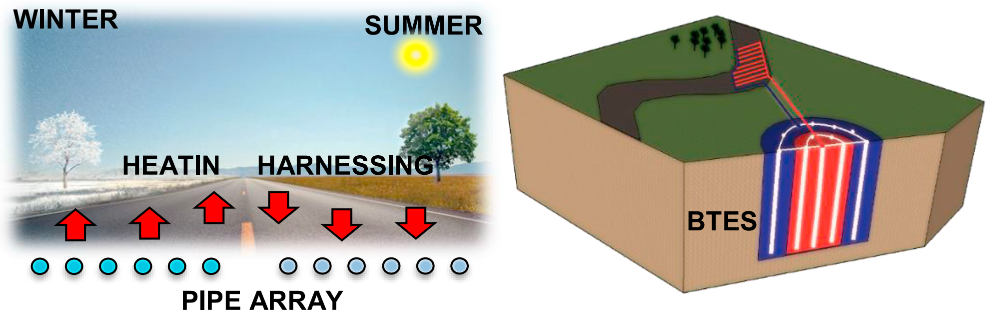

Fig. 1. Energy harnessing by asphalt pavement, storage and using during winter season.

Our research group investigates the utilization of hydronic pavement (HP) instead of traditional de-icing, see Fig.1. HP consists of a pipe network, embedded inside the pavement, in which a fluid is circulated. The fluid collects solar energy (using asphalt surface as a solar collector) during summer days and transports heat back to the road surface during icy winter days, see figure 1. The harnessed and released energy should be in balance, otherwise an additional heat source will be needed, [1].

4.2. Hybrid insulation in district heating pipes

Generally, it is of interest to lower the energy losses from district heating pipes both for economic and environmental reasons. The reduction of heat losses becomes even more important when the number of passive-, near zero- and plus buildings increases in a district. In the worst case the delivered energy to the building will be less than the heat losses in the network.

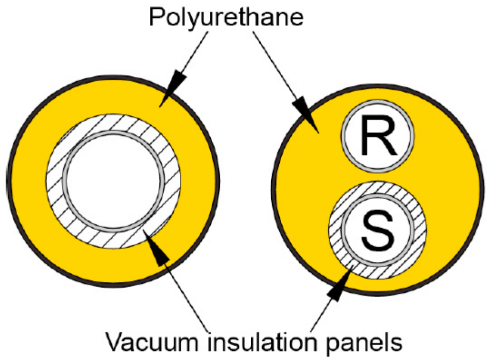

Fig. 2. Description of the hybrid insulation pipe concept. 'S' stands for supply pipe and 'R' stands for return pipe.

A hybrid insulation concept where Vacuum Insulation Panels (VIP) are put around the supply pipe in a district heating pipe was developed, see Fig. 2. The heat losses in a district heating network can be reduced by 25-30% by using hybrid insulation pipe [2]. Performance and service lifetime of the hybrid insulated pipes is under investigation at laboratory and in five field stations, part of a piping network, in Sweden. The monitoring results until now indicate that the service lifetime of the new concept with high thermal performance can be in the same level as the traditional solution.

4.3. Status assessment of district heating pipes

District heating pipe network deliver hot water to the building both for heating and domestic hot water. The supply water temperature is between 80-120 ^{0}C. The supply pipe is insulated by rigid polyurethane insulation (PUR). The heat losses in a typical district heat network in Sweden is 10%-15% and the service life of the pipes depending on the supply temperature level, can be 30-50 years. The thermal performance of the insulated pipe reduces due to aging of

PUR. Assessment of the thermal performance is necessary for making decision related to replacement of the piping network.

A new non-destructive method was developed in our research group for assessment of thermal performance of the piping network [3]. The method based on using thermal coefficient of resistances (TCR) in metals. Initial measurement and evaluation of the method is performed at Chalmers University of Technology. The next step is to apply the method in real conditions i.e. in a district heating pipe network.

5. Conclusion

There is a need for focused research related to physical behavior of the physical infrastructure. A new research group has been initiated at Chalmers Technical University with focus on 'Infrastructure Physics'. The research area 'infrastructure physics' treats the influence of outdoor climate on the short and long term performance of a physical infrastructure. Furthermore, 'Infrastructure Physics' deals with physics behind the phenomena related to physical behavior of the materials, components and systems involved in the infrastructure in their specific environmental conditions (underground, subsea, surface), in order to increase their accessibility and efficiency .

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