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Societal burden and engineering challenges of ageing infrastructure

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Abstract

Ageing is an inherent feature of nature and, hence, of materials, structures and systems. Yet, it seems a rather new topic in both science and engineering. The main reason for increasing attention for ageing as a topic is the growing awareness that, particularly in industrialized countries, ageing of our assets is a financial burden for the society. It touches our environment and a country's economy. It affects the overall sustainability of our planet and deserves, therefore, our utmost attention. In this contribution the urgency and challenges of ageing of concrete structures are addressed. Recent estimates of the extent of the issue and how ageing problems are dealt with in different disciplines, reactive or pro-active, are mentioned. The complexity of ageing problems will be evaluated by looking in more detail to the evolution in concrete mix design and the consequences thereof for the long-term performance of concrete structures. In this evaluation different kinds of driving forces contributing to ageing will be identified. Emphasis will be on ageing of concrete infrastructure and the need of research on ageing phenomena will be addressed.
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1. Infrastructure – Backbone of a country's prosperity

Architecture has been defined as the *art* and *science* of *designing* and *constructing* buildings and other physical structures for human shelter or use. In this definition the word shelter is meant in the broadest sense of the term. Going back to ancient times people needed shelter for protection against storms, rain and snow, direct sun shine and cold weather. For protection against hostile tribes cities were built surrounded by massive city walls. Dykes were built to protect against floods. Besides the need for shelter an increasing need for mobility emerged. For mobility of people roads and waterways were built. Aqueducts were built to transport water over long distances. With the

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industrial revolution there was also an increasing need of energy and energy transport, requiring the design and construction of energy supply systems. To save densely populated cities from catastrophic water pollution, sewage systems were designed and installed. Large railway systems were built to enable long-distance transport of people and goods by train. Via bridges, viaducts and tunnels otherwise isolated transport networks became connected. All this illustrates that a modern society is inconceivable without a well-developed physical infrastructure. An infrastructure which, according to Long [1], accounts for about 50% of the country's national wealth.

When putting this in a global perspective, the infrastructure's value has been rated at € 37 trillion [2,12]. This is the value of the *existing* infrastructure, which is considered crucial for the prosperity and well-being of our society. In this respect Gann [3] argues that "The construction's significance to wealth creation and quality of life extends *beyond* its direct economic contribution. The products create an infrastructure that supports existing and newly emerging social and economic activities". And he continues saying; "If inadequate or inappropriate buildings and structures are produced, or they are poorly maintained and adapted, then social and economic life is compromised".

In a recent study of the McKinsey Global Institute [2] estimates were published of future investments in infrastructure worldwide needed to ensure economic stability and growth. In order to catch up with the prognosticated economic growth an investment of more than € 41 trillion was considered necessary in the period 2013-2030. This figure included the infrastructure for transport (roads, ports, rail, airports), water, telecommunications and power plants. This amount was based on an evaluation of money spent on infrastructure in 84 countries, accounting for more than 90% of the global gross domestic product (GDP). Table 1 gives the breakdown of investments over different categories.

Table 1. Estimated needs for global infrastructure in different categories in the period 2013-2030 [2].

Category	Reference	Required investment [4]
		× € 1,000,000,000,000
Roads	OECD[1]	12.2
Rail	OECD	3.3
Ports	OECD	0.5
Airports	OECD	1.4
Power	IEA[2]	8.8
Water	GWI[3]	8.4
Telecommunication	OECD	6.8
Total		41.4

1) Organization for Economic Co-operation and Development
2) International Energy Agency
3) Global Water Intelligence
4) Conversion rate 2013: 1 US$ = € 0.73

There is no doubt: economic stability and growth are unconceivable without an appropriate infrastructure. Without this infrastructure the economy would come to a complete stop. The infrastructure, however, is subject to *ageing*. Our assets – roads, railways, energy infrastructure, etc. - are still in use, but many of them beyond their initially presumed lifetime. The ageing process to which our assets are subjected is not a matter of bad luck or poor workmanship. In essence it is a natural law. If ageing and its potential impact on the quality of a country's infrastructure is not well diagnosed, this may lead to a situation of uncertainty or even societal instability. It is for this reason that stakeholders want to increase their knowledge and perception of ageing phenomena. Owners want to know how long it will take before on-going ageing processes require intervention or result in damage or even fatal failure. For this purpose reliable predictive tools are needed to forecast the rate and impact of ageing processes.

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