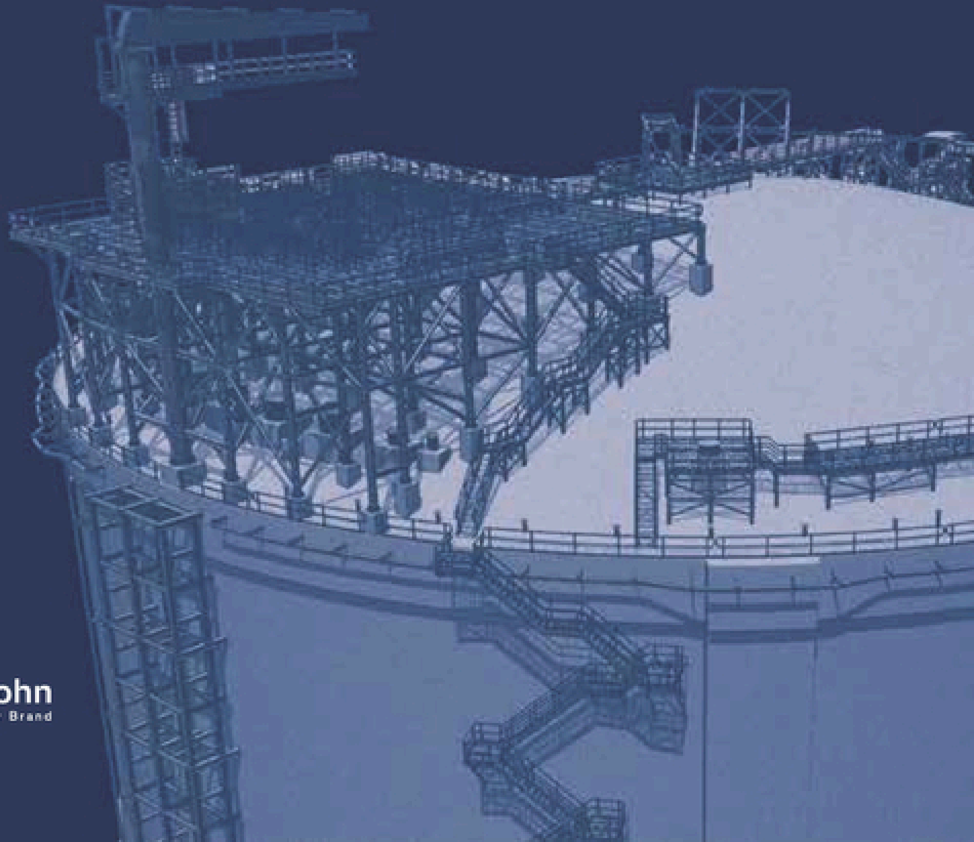
BetonKalender

Design and Construction of LNG Storage Tanks

Josef Rötzer



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Cover: LNG tank with typical steel structure
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Contents

Editorial

The *Concrete Yearbook* is a very important source of information for engineers involved in the planning, design, analysis and construction of concrete structures. It is published on a yearly basis and offers chapters devoted to various, highly topical subjects. Every chapter provides extensive, up-to-date information written by renowned experts in the areas concerned. The subjects change every year and may return in later years for an updated treatment. This publication strategy guarantees that not only is the latest knowledge presented, but that the choice of topics itself meets readers' demands for up-to-date news.

For decades, the themes chosen have been treated in such a way that, on the one hand, the reader gets background information and, on the other, becomes familiar with the practical experience, methods and rules needed to put this knowledge into practice. For practising engineers, this is an optimum combination. In order to find adequate solutions for the wide scope of everyday or special problems, engineering practice requires knowledge of the rules and recommendations as well as an understanding of the theories or assumptions behind them.

During the history of the *Concrete Yearbook*, an interesting development has taken place. In the early editions, themes of interest were chosen on an ad hoc basis. Meanwhile, however, the building industry has gone through a remarkable evolution. Whereas in the past attention focused predominantly on matters concerning structural safety and serviceability, nowadays there is an increasing awareness of our responsibility with regard to society in a broader sense. This is reflected, for example, in the wish to avoid problems related to the limited durability of structures. Expensive repairs to structures have been, and unfortunately still are, necessary because in the past our awareness of the deterioration processes affecting concrete and reinforcing steel was inadequate. Therefore, structural design should now focus on building structures with sufficient reliability and serviceability for a specified period of time, without substantial maintenance costs. Moreover, we are confronted by a legacy of older structures that must be assessed with regard to their suitability to carry safely the increased loads often applied to them today. In this respect, several aspects of structural engineering have to be considered in an interrelated way, such as risk, functionality, serviceability, deterioration processes, strengthening techniques, monitoring, dismantlement, adaptability and recycling of structures and structural materials plus the introduction of modern high-performance materials. The significance of sustainability has also been recognized. This must be added to the awareness that design should focus not just on individual structures and their service lives, but on their function in a wider context as well, i.e. harmony with their environment, acceptance by society, responsible use of resources, low energy consumption and economy. Construction processes must also become cleaner, cause less environmental impact and pollution.

The editors of the *Concrete Yearbook* have clearly recognized these and other trends and now offer a selection of coherent subjects that reside under the common "umbrella" of a broader societal development of great relevance. In order to be able to cope with the corresponding challenges, the reader can find information on progress in technology, theoretical methods, new research findings, new ideas on design and construction, developments in production and assessment and conservation strategies. The current selection of topics and the way they are treated makes the *Concrete Yearbook* a splendid opportunity for engineers to find out about and stay abreast of developments in engineering knowledge, practical experience and concepts in the field of the design of concrete structures on an international level.

Prof. Dr. Ir. Dr.-Ing. h. c. *Joost Walraven*, TU Delft
Honorary president of the international concrete federation *fib*

About the Author

Dr.-Ing. Josef Rötzer (born in 1959) studied civil engineering at the Technical University of Munich and later obtained his PhD at the Bundeswehr University Munich. From 1995 onwards, he worked in the engineering head office of Dyckerhoff & Widmann (DYWIDAG) AG in Munich. His area of responsibility included the detailed design of industrial and power plant structures. The DYWIDAG LNG Technology competence area, focusing on the planning and worldwide construction of liquefied gas tanks, was integrated into STRABAG International in 2005.

Josef Rötzer is a member of the Working Group for Tanks for Cryogenic Liquefied Gases of the German Standards Committee and a member of the committee for the American code ACI 376.

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Introduction

The use of natural gas as an independent branch of the global energy supply sector began in the early 1960s. Prior to that, natural gas had only been regarded as a by-product of crude oil production; there was no use for it and so it was either pumped back into the ground or flared. But all that has changed in the meantime – natural gas currently accounts for 22% of global energy supplies. Huge deposits in Australia are now being exploited and deposits in the USA will soon be coming online, which will increase that global share (Fig. 1.1). There are many reasons for this development – economic, political and ecological: Australia is close to the growing Asian economies, the USA is aiming to reduce its dependence on foreign oil and energy supplies by developing its own resources, and global efforts to replace fossil fuels by gas apply throughout the world.

The International Maritime Organisation (IMO), a specialised agency of the United Nations, has drawn up new rules that have been valid from 2015 and are particularly strict for the North Sea and Baltic Sea. Complying with emissions requirements is difficult when using diesel and heavy oil as marine fuel. But using liquefied natural gas (LNG) as a marine fuel results in – compared with diesel – about 90% less nitrogen oxide, up to 20% less carbon dioxide and the complete avoidance of sulphur dioxide and fine particles [1]. Det Norske Veritas (DNV), the Norwegian vessel classification body, therefore expects that there will be about 1000 new LNG-powered ships by 2020, which amounts to almost 15% of predicted new vessel orders. This change is heavily influenced by the huge drop in the price of natural gas, which has been brought about by the global production of shale gas (Fig. 1.2, Fig. 1.3).

The use of natural gas involves transport and storage difficulties. Transport via pipelines is economic up to a distance of 4000–5000 km, depending on the boundary conditions. In the case of difficult geographic circumstances, such as supplies to islands, e.g. Japan and Taiwan, or where it is necessary to cross mountain ranges, supplying gas via a pipeline is much more difficult and costly. Therefore, the method of liquefying natural gas and then transporting it over great distances in ships had already become established by the mid-20th century.

LNG technology takes advantage of the physical material behaviour of natural gas, the main constituent of which is methane. At the transition from the gaseous to the liquid state, the volume is reduced to 1/600. However, this requires the temperature of the gas to be lowered to -162°C. Only this extreme reduction

Design and Construction of LNG Storage Tanks, First Edition. Josef Rötzer.

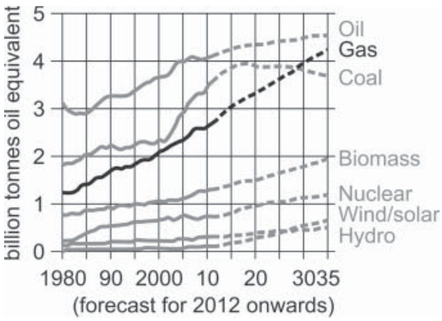

Fig. 1.1 Development of energy demand [1].

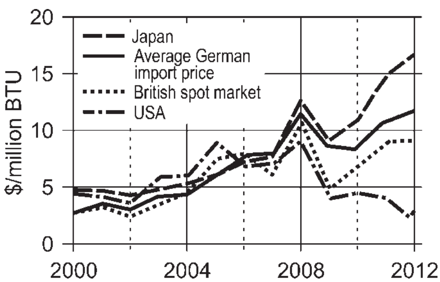

Fig. 1.2 Gas price developments since 2000 [1].

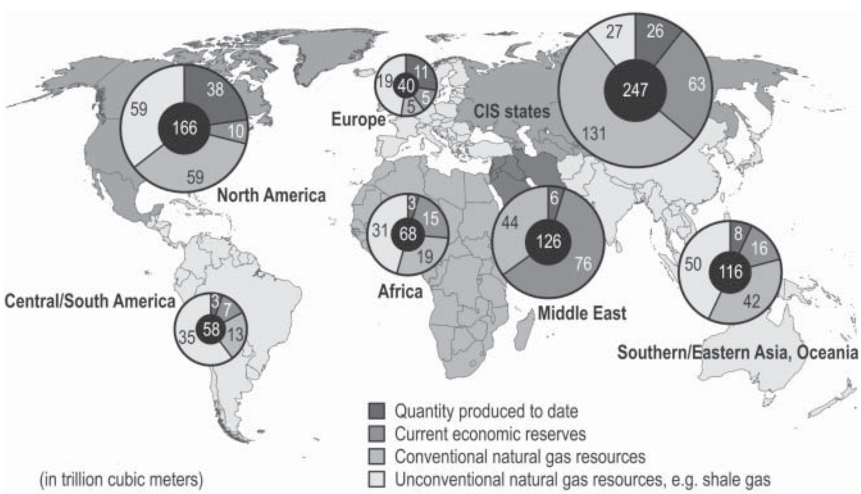

Fig. 1.3 Regional distribution of natural gas potential [1].

in volume makes transport in ships economically viable. The entirety of the elements required for transporting LNG in ships is known as the "LNG chain", which consists of the liquefaction plant in the country supplying the gas, LNG tanks for intermediate storage of the liquefied gas, jetties as berths for the special LNG transport vessels, tanks for the intermediate storage at the receiving (i.e. import) terminal and a regasification plant in the country importing the gas.