PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
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CONDITIONS FOR USING CONCRETE AS A CONSTRUCTIONAL MATERIAL IN ARCTIC HARBOURS

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Abstract:
The paper briefly deals with difficulties in applying ordinary concrete technology and manufacturing techniques for constructional works in the Arctics. It is suggested to use precast concrete, manufactured in bulk-carriers, equipped with complete concrete plant facilities for big-size Arctic harbours. Perspectives in concrete technology are presented to the support of this proposal.

HISTORY

Generally, concrete has not been widely used as a constructional material during the early establishment of habitation in Polar regions. Thus, it is rather an exception to find in:

> *Den Norske Ingeniørforenings Betonkomité:*
> *Meddelelse nr. 3: Betong i Sjøvann*
> (The Norwegian Civil Engineering Society's
> Concrete Committee: Concrete in Sea Water)
> Oslo 1936, [1]

an extensive description of North-Norwegian harbour works, dating back to 1883 (Vardø Pier, Hammerfest Pier), 1889 (Hovden Pier), 1914 (Omgang Pier) and others. Apparently, in those days Norway has seen a relatively prosperous trade (fishing, hunting, wood and timber, agriculture) and population development as motivation for supporting the habitation of the Finmark-area, and the contemporary civil engineers have been able to foresee the technical possibilities in using the newly invented concrete as the constructional material.

The 1936 report deals with a nation-wide investigation of the behaviour of concrete exposed to sea water, carried out during the early thirties and at that time a topic much discussed among harbour authorities, consultant engineers, research experts etc. all over Europe and America.

The Norwegian observations on the behaviour of up to 40-50 years old concrete are interesting to read about even to-day. They show that well manufactured concrete has withstood the extremes of environmental exposure surprisingly well. They also demonstrate (although this is not explicitly recorded) that it has not been easy to make good concrete under the actual working conditions. Among these, the remoteness of the working sites, and the general ignorance of the requirements for making concrete good have had quite obvious effects. Still, one gets the overall impression that even rather bad concrete (lean, badly compacted, non-homogeneous) which has demanded repairs under its function time, has served its local communities well. After all, these were small habitation units with no resources on which to base larger investments.

One can also see, of the records and their evaluation, that concrete from around 1890 was found in excellent condition about 40 years later, provided that reasonable requirements for the concrete making had been met. In this respect, the descriptions and evaluations of the report are well in accordance with the more recent investigation of concrete in Norwegian harbour work by O. Gjørv [2].

Both publications also tell that the kinds of constructional works utilized in these older harbours were mainly two: coverage piers for which either concrete blocks, or solid concrete walls were used, and loading piers, consisting of reinforced decks, supported by discrete piles, most often cast in situ by means of the tremie-procedure for underwater concreting.

FUTURE

In discussing PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS in 1971 it is natural to distinguish between:

1. Small harbour works at remote places, where no sophisticated mechanization can be invested
2. Larger urban development schemes, where an e-volutionary growth of works and their use must be considered
3. Big civil engineering works for mining etc., where transport of concentrated supply goods and bulk-materials are to be handled at high capacity demands

Small harbour works

When the above mentioned Norwegian surveys of the behaviour of concrete in harbours under Arctic conditions are reconsidered in the view of modern concrete technology, one must conclude that as far as simple concrete making is concerned, there are no serious problems left, one can safely rely upon the trial and errors of the past.

When prescribing concrete materials, concrete composition and the job-execution procedures we can meet a wide variety of local conditions: technical, economic and environmental, e.g. aggressivity of climatic exposure.

In fact, what remains to be made is an up-to-date compilation of this know-how in an international set of simple working rules. This task could probably be undertaken as a group-study by a university concrete technology department.

Urban development schemes

The above view on concrete making at small remote sites applies also to a certain extent for harbours and coastal works at larger urban development schemes in Arctic regions, where some degree of mechanization will be available, for instance crushing and screening plants for aggregates, batching plants, vibration equipment, heating facilities for acceleration of the hardening of concrete, simple testing laboratories etc. Under such conditions also the possibility to produce precast concrete may exist, provided high depreciation rates of the technical facilities are politically acceptable.

Also under such conditions we know well how to specify concrete materials, composition and handling during and after manufacture, it be as site-work or in precast plants. The formula to apply simply says:

Prescribe according rules for making first class concrete under temperate climates, adjust these rules after local job-situation and Arctic climate and use a qualified task force for adequate control and testing. *Again, an international compilation of adequate specifications for this type of concrete making would be beneficial to have. Safeguards towards the climatic exposure would have to be emphasized.* Early recommendations for winter-concreting from Canada, USSR, Denmark etc. [3], might provide a useful basis for a review of available knowledge.

There is no need, in the present paper, to discuss such specifications in greater detail, as this problem predominantly concerns quite conventional concrete technology.

<u>Big civil engineering works</u>

Recent years' explosive increase of communication with Arctic regions mainly derives from:

1. The development of huge bulk-carriers and appurtenant means of navigation
2. The intensification of exploration and mining of ores for industries working in urbanized regions
3. The defense demands for utilization of Arctic regions

High capacity and rate of manufacturing will be demanded for any civil engineering work to serve the two latter purposes. This calls for unconventional thinking with regard to the utilization of materials for harbour construction.

Let us consider a rocky Arctic ocean coast open to the full impact of seas and winds, currents, icebergs, severe freezing and snow almost throughout the year.

If such a place is rich in ores, it may be of the utmost importance to build a loading pier in the shortest possible time, though at the same time it may be quite impossible to go ashore with civil engineering teams and equipment for the erection of a working site. Obviously, this calls for such an extent of premanufacturing that a bulk-carrier fully equipped as the working-site might be the solution.

A 100.000 - 200.000 BRT ship would be able to carry, even for a quite considerable civil engineering job:

1. stockage of concrete materials
2. plant for industrialized concrete manufacturing
3. storage space for manufactured concrete products, e.g.: heavy blocks for external pier fillings, constructional members for loading piers etc.

Sailing distance for the "carrier-plant" from bases in temperate climate regions would be, say 4-10 days. In applying advanced concrete manufacturing technique a considerable amount of concrete blocks can be ready for disembarkement from the carrier on arrival to the selected location. Further concrete manufacture can go on continuously, smaller bulk-carriers being used as supply freighters for concrete materials. Upon completion of the construction task the "carrier-plant" may either contract other suitable enterprises or scrap the concrete manufacturing equipment and be converted into an ore shipping carrier. Needless to say ores might well be concrete aggregates, of which adequate qualities are nearly used up in some of the densely populated regions of the world, as e.g. in Eastern US, Japan.

To produce concrete on board a sailing vessel ought to be considered a quite natural procedure among other daring enterprises in Arctic harbour construction.

Industrialized manufacture of concrete, and use of precast concrete members have already, even for complicated constructional work, conquered the market in densely populated regions. Consequently, increasing concrete research and development efforts are aiming at:

1. Considerable reductions of concrete processing time
2. Considerable improvements of concrete strength, density, durability etc.

A "state of affair" - survey demonstrates that a broad aspect of available or reachable concrete technology possibilities exist:

Cements: - The homogeneity of ordinary types and brands of cements is at present intensively studied in cement industries, and reductions of strength variations, (of more importance in industrial concrete processing than in conventional building site work), are attainable. New types of cement, with instantaneous or quick, controlled setting and strength development, are under development and have somewhere commenced to reach the market. Basic problems of cement mineralogy and hydration are now being attacked with much more powerful research tools than ever before.

Aggregates:- Huge deposits on the sea bottoms of excellent, naturally screened and washed aggregates are now being made available by dredging down to about 100 meters depths from ships loading up to 10-15.000 tons materials. Industrial crushing of solid rocks is also developing, with easier choice than before between light or heavy rock types, where protection of natural life does not prevent utilization.

In several countries large stockages of rock waste from old-time mining are investigated for utilization, and excellent aggregates are now being produced from industrial waste like fly-ash, slag etc. (Great Britain, for instance, could have its entire consumption of concrete aggregates covered until year 2000 by processing already available stocks of unused fly-ash). Still larger quantities of several types of artificially manufactured aggregates, as for instance expanded shale and clay, are produced with properties according the demands of the market, including optimized granulometry.

Fibre reinforcement of the matrix of concrete, the cement paste, has come under intensive research at many university and industry laboratories. Fibrous glass, plastics, steel are being tried, and the competitive motivations seem strong enough to ensure that interesting technological possibilities will appear.

Admixtures: - Many basic physico-chemical problems regarding the effects of admixtures on fresh and hardened concrete remain to be explored. But the empiric progress in increasing the versatility of concrete by means of admixtures is spectacular. The existence and effects of accelerators, plasticifiers, air-entrainment agents are well known.

More recently polymerization of concrete, impregnated by means of plast-monomers have been explored in several countries,[4], [5],[6], and improvements of strengths, impermeability, durability etc. of 5-6 times conventional levels have been attained, i.e. up to about 2000 kg/cm^2 compressive strength.

Fresh concrete: - Careful utilization of conventional concrete materials and manufacturing methods makes high-quality products, e.g. for prestressed structural members etc., a common market feature to-day, final compressive strengths reaching the 6-800 kg/cm^2 level. More scientifically based compaction methods are promising strength levels of, say 12-1400 kg/cm^2 to be attainable in the nearer future. These techniques, at the same time promise much quicker form-removals than ordinarily needed and also increase of the concrete density (on which the strength primarily depends) up towards the 3.0 g/cm^3 level.

Setting and hardening: - In applying chemically acting accelerators, in providing heating to the concrete and in deliberately utilizing the heat of hydration, a variety of techniques can be applied. If cunningly integrated and controlled, manufacturing of high-quality concrete in a 6-8 hours complete cycle is now a technological possibility. Further reduction of processing time will come.

Durability: - In applying the procedures suggested above for concrete manufacturing:

careful selection of materials
industrial processing
avoidance of manufacturing under Arctic conditions

most concrete durability problems like resistance against wear and tear, frost, sulphates from the sea, alkali-aggregate reaction etc. will automatically be omitted, and full advantage can be taken of the concrete characteristics in general.

The perspectives described with regard to concrete process- and product development derive from a such variety of sources of improvements that although a simple addition of potentials cannot be realistic, there must remain a solidly based conviction that industrialized concrete, say in the course of the next 10 years will be made at half the processing time of to-day, at the same time doubling the magnitude of the functional characteristics. This means that innovative companies and authorities probably will reach that level of technique in about 5 years, while naturally most concrete making will remain in a much slower evolution of techniques. One may ask in conclusion, which are the handicaps counteracting the presented concept of the development.

First of all, one must admit that most concrete research of to-day is still typically piece-meal activity, not aiming at industrial process- and product innovation, and thus even in great measure contributing to maintaining conventional practice.

Secondly, one must also admit that very few civil engineering or industry companies are asking research to work with progressive intensity and integrated efforts on goals, defined in technical/ economic terms.

Thirdly, the entire chain process: invention, research, innovation, industry development, marketing and sales is but little understood by present days' civil engineers involved in concrete research, in civil engineering business or for that sake among the government personnel, who are responsible for building performance requirements, codes of practice etc.

Big size harbour construction enterprises might provide the challenge, which can make us overcome these handicaps.

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