EXECUTIVE SUMMARY

The existence of Alkali Aggregate Reaction (AAR) in Norwegian concrete structures has been demonstrated in this Thesis. The reaction is of the slow/late-expansive type developing over decades and takes place mainly in the "coarse" aggregate fraction. AAR in Norwegian structures has also been caused by a high content of alkalies in Norwegian cements (during the course of decades) and occurs mostly in structures situated in environments with high humidity.

In Southern Norway three field inspections have been carried out and 468 road bridges, hydropower plants and dams have been recorded for map cracking and signs for AAR. At the present time "deleterious" AAR has been diagnosed in 31 dams, hydropower plants and road bridges older than 18 years and "minor reactions" due to AAR in 2 structures. Map cracking is common in Norwegian structures, but seems to be more frequent in structural elements eg. foundations with high humidity and in structures located in potentially alkali reactive rock areas. The majority of structures where AAR has been diagnosed are also map cracked and located within or close to areas with substantiated potentially alkali reactive rocks. For the reason, that map cracking can be caused by other processes than AAR, this should always be substantiated by petrographic methods in each case. More cracking occurs in Norwegian structures built between 1950-1960 than other periods. However, the reason for this occurrence of cracking is unknown. Volume expansion due to AAR has caused problems in a few hydropower plants and dams. The reduction in the size of expansion joints (sometimes to zero) has been observed in several structures, and could give problems if further expansions occur.

Petrographic examinations of cores, fluorescence impregnated polished half cores and thin sections from structures have been used to diagnose AAR. Typical reaction signs in Norwegian concretes with deleterious AAR are reaction rims, precipitation of white reaction products in "larger" air voids, dark zonation around reacted aggregates, cracks in aggregates and the mortar phase. Reaction products in the form of gel, cryptocrystalline reaction products and lamellae crystals/fan-shaped agglomerates normally occur close to reacted aggregates and/or within reacted aggregates. Ettringite-like crystals occur in concretes with and without AAR and these are probably a form of secondary precipitation caused by the high humidity in these concretes, rather than AAR.

AAR in Norwegian structures is caused by the "coarse" fraction of slow/late-expansive aggregates of same types as reported elsewhere e.g. in Canada. More or less diagenetic to low grade metamorphosed rhyolites, sandstones, siltstones, argillites (some carbonaceous), graywackes, and phyllites have reacted. More uncertain AAR has been caused by granite, gneiss and hornfels. Cata-clastic rocks e.g. cataclasite and mylonite have been observed deleterious alkali reactive in about 50% of all the investigated Norwegian structures. Image analyses of the matrix phase of reacted aggregates have revealed the most common grain size to be both 12-20 micrometres and 36-60 micrometres. Strained quartz, developments of "sub grains", cataclasis and recrystallization of quartz are common in Norwegian alkali reactive aggregates, and the minerals *quartz-feldspar-muscovite (sericite)* are the most frequent composition in reacted Norwegian aggregates.

Laboratory testing, aiming to substantiate suitable test methods, have been carried out on several aggregate types which have been proven to be alkali reactive in field concretes as well as some innocuous aggregates. The most promising test methods for Norwegian aggregates seem to be the South African NBRI accelerated mortar bar test and the Canadian CAN3-A23.2-14A concrete prism test. The ASTM C 227 mortar bar test, the Danish accelerated mortar bar test TI-B 51, the Danish chemical shrinkage TK 84 test and the Japanese Fresh Con CBRI rapid test all failed to reveal alkali reactive aggregates or gave dubious results.

Comprehensive investigations of reaction products from field concretes and laboratory samples by thin sections, SEM/EDX, XRD and DTA/DTG show that reaction products in Norwegian concretes are more or less similar to those reported in international literature dealing with slow/late-expansive aggregates. However, lamellae crystals/fan-shaped agglomerates observed in some reacted sandstones, graywackes and mylonites are not known to have been reported earlier. EDX analyze results reveal that cryptocrystalline reaction products (platy crystals) from both aggregates and air voids are potassium rich and depicts into the same "composition" cluster which suggest the same origin. Lamellae crystals/fan-shaped agglomerates from aggregates depicts into another adjoining cluster. Two trends have been depicted, too. One for gel which has reacted with the cement paste and another one for sodium rich reaction products.

A hypothesis on the sequential development of AAR in Norwegian slow/late-expansive aggregates has been proposed. This explains how dense, less permeable and well crystalline aggregates, as the Norwegian, are able to react with the concrete pore solution. However, the hypothesis is based on petrographical observations and SEM/EDX analyses only, and should be better substantiated.
The following results are important for the processing and documentation of AAR in concrete structure as well as for preventive measures to minimize the risk for AAR in new structures:

- Construction of a database and map plots showing the distribution of 1) investigated and classified structures, 2) potentially alkali reactive rocks and 3) cataclastic rocks.

- Descriptions/lists of 1) typical reaction signs due to AAR in concretes, 2) reaction products and 3) alkali reactive aggregates

- Recommended laboratory tests methods and procedures for aggregates

This work is hopefully a step in the right direction, rather than a conclusive study. It must be remembered that Norway is a large country with a complicated geology and great climatic variations. Furthermore, at present, only a limited number of structures have been investigated for AAR. Therefore, some improvements of the conclusions that have been presented should be subjected to future research.