Annual report 2007

1. Summary

The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness implies aesthetics, functionality, sustainability, energy efficiency, indoor climate, industrialized construction, improved work environment, and cost efficiency during the whole service life. The primary goal is to fulfil this vision by bringing the development a major leap forward by more fundamental understanding of the mechanisms in order to develop advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

One main task in 2007 was to establish a uniform understanding among the partners of what COIN is and of the success criteria. Another main issue was to agree about the technical focus areas as result of the partner's needs plus social and environmental needs. Both were reached through a workshop 5-6 March, with more than 25 participants from all partners. The main technical activity in 2007 has been to agree on the technical projects and sub-projects and then to prepare the state-of-the-art within these fields. It has resulted in 17 state-of-the-art-reports. 7 papers in proceedings of international conferences and journals comes in addition.

The projects are:
1. Advanced cementing materials and admixtures
2. Improved construction techniques
3. Innovative construction concepts
4. Operational service life design, and
5. Energy efficiency and comfort of concrete structures

The Consortium has a Board of Directors, an Advisory Committee, a manager and a management group. The centre is located in Trondheim with SINTEF Building and Infrastructure as host institution. The Board has eight members; six from the industry partners, one from NTNU and one from SINTEF. All partners are represented in the Advisory Committee.

The consortium partners represent the value chain of the business sector; various material suppliers, contractors and users. They represent leading multinational companies in the cement and building industry. The partners cooperate through the work in the projects (technical work and joint meetings) and in the Advisory Committee. The centre got a new partner in this first year.

Recruiting of PhD students and researchers was difficult. But during the year eight PhD students were engaged with NTNU and SINTEF, and 2 researchers were employed with SINTEF, which is considered to be acceptable. The accumulated cost in 2007 was NOK 25.9 mill.

2. Vision and goal

The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness implies aesthetics, functionality, sustainability, energy efficiency, indoor climate, industrialized construction, improved work environment, and cost efficiency during the whole service life. The primary goal is to fulfil this vision by bringing the development a major leap forward by more fundamental understanding of the mechanisms in order to develop advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

The corporate partners are leading multinational companies in the cement and building industry and the aim of COIN is to increase their value creation and strengthen their research activities in Norway. Our over-all ambition is to establish COIN as the display window for concrete innovation in Europe.

3. Research plan - social, environmental and industrial needs

The research plan is based on the social, environmental and industrial needs referred below. These needs were addressed by the Consortium Partners in the application process and made more specific in a 2-days workshop at the start of COIN, and in the ongoing ECO-serve thematic EU network, with main objective to identify the needs of the European Construction Industry in its endeavour towards sustainability of the industries' products and production processes involving cement, aggregate and concrete production.

Innovation potential

The construction industry is one of Norway's largest with an annual turnover of approximately EUR 45 billion. According to a strategy document[1], innovation can release an annual value creation potential of EUR 3-4 billion. Concrete is the dominating construction material in buildings and infrastructure with an annual volume of 7 million ton. The concrete industry has documented significant value creation for the industry and the society with a yield rate of 19 on R&D investments from 1980 to 2000[2]. In this period

1 BAE/council> Research and development in the construction industry. Challenges and value creation potential. Part 1&2.Sept 2002.
2 Moksnes, J> What is the value creation from R^D in the concrete field in Norway in the period 1980/2000_ NCA Publ No 28, 2002

the Research Council provided essential funds triggering the R&D engagement of the industry. Again, there is a potential and a will in the industry to bring concrete innovation into a new era by development of; new high tensile strength cementing materials reinforced with microfibres; fibres replacing steel re-bars in SCC; super light weight concrete in sandwiched elements revolutionizing not only the building industry but even the ship building and offshore industry; as well as by other feasible achievements addressed in COIN.

Image and customers needs

A major challenge facing the concrete industry is the paradox that it is an essential necessity but yet has a low public image. This was pinpointed in a recent article in one of Norway's largest newspapers, Dagbladet, on the role of concrete in modern society with ingress: "Concrete glues every thing together, but it is not talked about, and it is disliked". Hence, it is an important issue for the industry to create a more realistic and positive image of their products. It is likewise important to make concrete buildings more attractive in order to gain a stronger position among building owners, architects, contractors and in the public opinion, and thereby increasing the marked share especially on housings.

The traditional focus of the companies within the concrete industry has been on volume sales (i.e., m^3 of concrete or tons of cement) and not sufficiently on the totality. In marked analyses, the industry is criticized by owners, architects and consultants for a lack of understanding of their customers' requirements and needs, and for not taking responsibility for the quality of their end products. These analyses also revealed a lack of confidence in the ability of the concrete industry to deliver products with predictable quality.

These challenges are not unique for the Norwegian industry but common to all modern countries and the industry has started to address them. The Concrete Centre in UK and "Bygg uten grenser" in Norway are examples on how the concrete industry joins forces to promote the benefits of concrete constructions addressing their customers' needs as well as providing easy access to information for their own members.

Alongside promotion there is also an urgent need for a major technology development in order to deliver more attractive buildings, improve the efficiency, reduce the construction and service life costs, and improve the work environment, in order to meet the need of customers and the society.

A goal is therefore to improve the quality of concrete products and to make it even more cost efficient and environmentally friendly.

Productivity

As for the building industry as a whole, the concrete industry faces challenges with respect to productivity, quality, work environment (HSE) and recruiting skilled workers. These challenges interact as the skills influence the quality (e.g., faults, defects, progress) and hence, the productivity. The physically hard outdoor work makes it increasingly difficult to recruit young people while skilled workers retire early.

The productivity in the construction sector has during the past decade for several reasons had a negative development compared with other industries. Technical improvements may significantly reduce the required work force and counteract this trend. Self-compacting concrete (SCC) has the potential for such achievements but it is still hardly used for ready-mixed concrete (2% of total volume). Further development of SCC into a complete construction concept combined with fibres

will significantly improve the efficiency. The working environment will also be improved due to less noise and strain injuries. In order to further improve the product quality, productivity and the work environment there will inevitably be an increased trend towards tailoring of properties and a higher degree of (indoor) prefabrication and premixed products.

A goal is therefore to develop more rational production and to increase the level of competence in this sector.

Sustainability

Sustainable development will still be emphasized by European and National politicians in the coming years. The sustainability of buildings and structures is strongly influenced by the choices made in design and construction, and it should be evaluated for the whole service life of the building. Concrete is a durable material offering a long service life and low maintenance costs. Recent studies reveal the possibilities for significant reductions (>50 %) in energy consumption for heating and cooling of buildings by adequate utilisation of the high thermal energy of concrete. This requires exposure of concrete surface and provides a potential for multifunctional construction elements with built in air storage for optimal air conditioning, surface textures and coatings to facilitate cleaning, and coloured concrete for improved aesthetics.

A goal is to develop designs and construction systems for significant reductions in energy consumption for heating and cooling of buildings by adequate utilisation of the high thermal energy of concrete.

With respect to sustainability the concrete industry also faces challenges related to environmental impact, depletion of resources and energy consumption. Being a “natural” material, utilization of concrete implies consumption of a vast amount of raw materials. Thus, the industry is facing rapidly increasing challenges related to global environmental requirements and supply of resources that force the concrete industry to look for alternative solutions. The main challenges are to significantly reduce raw material consumption, energy demand and emissions, while maintaining the market share. These issues are addressed in the ongoing ECO-serve thematic EU network, with main objective to identify the needs of the European Construction Industry in its endeavour towards sustainability of the industries' products and production processes involving cement, aggregate and concrete production.

A goal is therefore to improve the sustainability through development of technologies for reduced raw material and energy consumption and for low emissions, while maintaining the market share.

Environment

Aggregates for concrete have been quarried from natural resources. Now, an increasing amount is produced from crushed rock (but also secondary raw material, demolition waste, etc) because the natural resources are emptied or rejected for environmental reasons. However, even rock quarries meet environmental restrictions all over Europe. Production of cement is associated with high CO_2-emission. Although considerable progress has been made in optimisation and utilization of alternative materials and fuels, it still accounts for about 5 % of the world’s total CO_2-emissions. The Cement Sustainability Initiative (CSI), a program of the World Business Council for Sustainable Development has been formed to help the cement industry to address the challenges of sustainable development, and it provides regular up-dates on status.

To meet these environmental challenges the concrete industry needs to reduce material consumption, develop alternative and more robust materials, lighter products, new construction and design techniques.

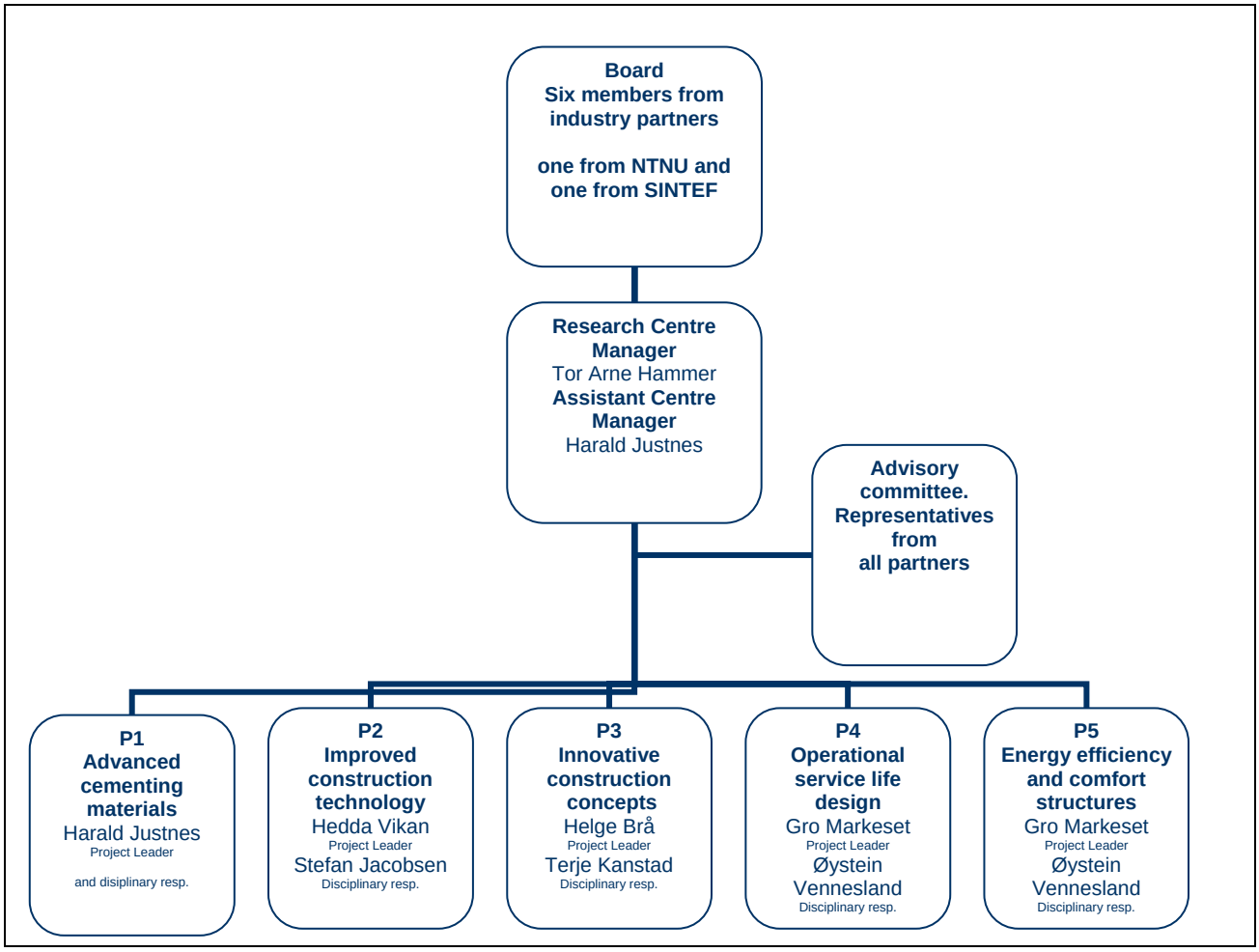
High performance concrete for harsh climate
The offshore industry pushed the limits for concrete application with the development of high strength and also LWA concrete in Norway in the 1980 and 90-thies. Technologies that later were applied also in onshore construction. Today natural gas transport on huge water depths, offshore storage tanks for liquefied natural gas and oil production in cold climates again push the limits for high performance concrete with respect to material composition and execution. Opening up the Barents Sea for oil production will challenge material and structure performance in this harsh climate, where ice abrasion is a decisive factor, and push the development further.

Fundamental approach
Research areas like SCC, fibre reinforcement and blended cements are not new, but the research have up till now been to a large extent empirical. A more fundamental understanding of the mechanisms is required in order to bring the development a major leap forward. As an example, traditional steel reinforcement may be completely replaced by fibre reinforced SCC and light composites. However, this requires a fundamental understanding of the interaction of cement paste and fibres and on how it can be optimized.

4. Organising

The Consortium has a Board of Directors, an Advisory Committee, a manager and a management group. The Centre's manager reports to the Board.The centre is located in Trondheim with SINTEF Building and Infrastructure as host institution and with Senior Research Engineer T.A. Hammer as Research Centre Manager and Chief Scientist Professor H. Justnes as Assistant Centre Manager. The Board has eight members; six from corporate partners, one from NTNU and one from SINTEF. All partners are represented in the Advisory Committee (AC). AC act as a technical expertise group and assembles at least twice a year. AC consider and decide the annual work plan to be recommended for the Board.

The centre operates in close cooperation with NTNU Faculty of Engineering Science and Technology. Three professors at the Department of Structural Engineering (Kanstad, Jacobsen and Vennesland) are disciplinary responsible for 4 projects. The centre uses the laboratory facilities of NTNU and of SINTEF in Trondheim as well as in Oslo.



The senior personnel is made of the management group and the disciplinary responsible persons at NTNU.

The consortium partners represent the value chain of the business sector; various material suppliers, contractors and users. They represent leading multinational companies in the cement and building industry. The centre got a new partner (Spenncon) in the first year.

Aker Kvaerner Engineering & Tehnology is one of the world's leading offshore technology companies and a part of Aker Kværner ASA

Borregaard LignoTech is the world's leading producer of lignin-based products, i.a. as concrete admixtures, and a part of Borregaard. They have their own laboratory and research staff.

maxit Group AB is the market leader in Europe on dry mortar, lightweight aggregates and building chemicals products. maxit Group is present in 25 countries. They have their own laboratory and research staff.

Norcem AS is Norway's sole producer of cement and a part of the Heidelberg Cement Group (DE), one of the worlds leading producers of cement, and an associated company to the ready-mixed concrete company NorBetong and its subsidiary NorStone, Norway largest producer of concrete and aggregates. Norcem coordinates the Groups R&D activities in Norway.

Rescon Mapei AS is a part of the Mapei Group (IT), one the worlds leading producers of admixtures and additives for concrete as well as adhesives and chemical products for the building industry. Rescon Mapei has their own laboratory and research staff in Norway.

Spenncon AS is part of Consolis SAS (BE) which is one of the largest manufacturer of prefabricated concrete products in the world. Spenncon acts on behalf of the Scandinavian Branch of Consolis; Spenncon, Parma and Strängbetong, as well as of Consolis Technology.

Unicon AS is a part of Unicon A/S (DK), which is the largest ready-mix concrete producer in Scandinavia and a subsidiary of Cementir SpA (IT), a world leader in production of white cement.

Veidekke Entreprenør ASA is a part of Veidekke Group, a leading building contractor and property developer in Scandinavia.

Norwegian Public Roads Administration (NPRA)is an autonomous agency subordinated the Norwegian Ministry of Transport and Communication. They have their own research staff and laboratories, and provide guidelines for design, construction and maintenance of roads, tunnels and bridges.

The **Norwegian University of Science and Technology** (NTNU) represents academic eminence in technology and the natural sciences as well as in other academic disciplines.

The **SINTEF Group** is the largest independent research organisation in Scandinavia with more than 90 % of its income from contract research.

The partners cooperate through the work in the projects (technical work and joint projects meetings) and in the Advisory Committee. More than 4 partners are represented in all projects except one (Project 5). Four partners have personnel taking part in the MsC education at NTNU.

An important event setting terms for the cooperation and the technical content was the workshop 5-6 March, with more than 25 participants from all partners: A uniform understanding of what COIN is and of the success criteria was reached, as well as agreement about the technical focus areas as result of the partners needs plus social and environmental needs.

5. Technical activities, results

The discussion at the March workshop resulted in five projects, representing the previous mentioned social, environmental and industrial needs. Also, the projects are organised to cover every partner's main interest. Detailing and subdivision was made in following projects meetings with the partners.

The main technical activity in 2007 has been to agree on the technical projects and sub-projects and then to prepare the state-of-the-art within these fields. It has resulted in 17 state-of-the-art-reports. The projects are:

1) Advanced cementing materials and admixtures

- Cements with lower CO_2 emission during production
- Admixtures to control hydration development
- Cements and admixtures to prevent cracking
- Alternative pozzolana
- Cements with lower porosity

Industry partners with main interest in this project are Norcem, Rescon Mapei, Borregaard and maxit. There is a PhD student on the first sub-project. We have found a new admixture in the second activity which is very promising in order to accelerate the setting (solidification) of concrete. Another important finding is the possibility of using easy available clay sources to make calcined clay as alternative pozzolana (to e.g. silica fume and fly ash).

2) Improved construction techniques

- Concretes with rheology adapted to rational production methods
- Concretes with high fibre content to be used in load carrying structural parts
- Concretes and production techniques to give good looking surfaces
- Technology for production of optimal crushed aggregate

Industrial partners with main interest in this project are maxit, Norcem, Unicon and Veidekke. One PhD student is engaged in this project. In 2007 a forum for discussion of future efficient construction solutions with concrete, combining materials design/materials properties, production techniques and structural design concepts, were planned. An unique large scale system for studying pumping of concrete was established in the laboratory.

3) Innovative construction concepts

- Design and verification basis for utilization of fibres in load carrying structures
- Development of superlight high performance aggregate and concrete
- Hybride structures – development of new material combinations, e.g. to be used in arctic environment

Industry partners with main interest in this project are Veidekke, maxit, UNICON, Aker Kværner and Statens Vegvesen. At the end of 2007 there were three PhD-students engaged in the project. The most significant achieved milestones were:

- Nordic miniseminar on fibre reinforced concrete, Nov 5th, Trondheim, Norway
- Workshop on ice abrasion on concrete, Oct 25th - 26th, Helsinki, Finland, worldwide participation representing state of the art of the topic
- Re-establishment of three-dimensional stress rig

4) Operational service life design

- Reliable and operational tools for prediction of service life for new structures as well as residual service life for existing structures exposed to corrosion
- Efficiency of preventive measures to increase service life (surface treatments, inhibitors, low corrosive reinforcement, etc)

Industrial partners with main interest in this project are NPRA, Norcem and Rescon Mapei.

At the end of 2007 there were two PhD-students engaged in the project.

The main conclusions from the state of the art review are:

- For existing service life models for chloride induced corrosion statistical data for the relevant durability parameters are lacking.

- Operational service life models including the corrosion process is lacking and increased knowledge and research is needed to develop more reliable models.
- Quantification and modelling of the efficiency of preventive measures on the service life are lacking

Preliminary results reveal that there is a need for changing the accept criteria in national and international regulations concerning alkali-aggregate reaction. This has been announced to an international pre-standardisation committee. The committee is chaired by representatives from the COIN partners.

5) Energy efficiency and comfort

Utilization of the thermal mass of concrete to reduce the need for cooling/heating of buildings, and its consequence for the indoor climate

Unicon is the industrial partner with main interest in this project.

So far calculations using improved models show that the energy consumption for cooling in office buildings may be eliminated by utilisation of the thermal mass, and that the indoor environment may be significantly improved.

6. International cooperation

Partners and key persons represent broad international cooperation by virtue of local networks within the multinational partners, personal networks and of committees. The centre has started to structure it for best possible utilization. One results of this is a cooperation within ice abrasion (Project 3), which started with the workshop in Helsinki. The parties in this cooperation are leading in research on ice technology and abrasion:

- Helsinki University of Technology (TKK), Finland
- Laval University, Canada
- Dartmouth College/Thayer School of Engineering, USA
- Cold regions Research and Engineering LaboratoriesUSA

We are continuously evaluating the possibilities of participation in or preparing proposal for relevant EU-projects (i.a. through participation in EU “partnersearch” meetings). We did find any relevant possibilities in 2007.

We applied for membership in Nanocem (www.nanocem.net), a European research network comprising nearly 40 partners, established to generate basic knowledge on the nano- and microscale phenomena which affect the essential characteristics of cement and concrete. The network does not allow project organisations (such as COIN) to be a partner of formal reasons. Therefore, the COIN host (SINTEF Building and Infrastructure) applied and became member from March 2008.

Other kinds of international cooperation:

- Two students from the University of Freiberg worked for 6 months in Project 3
- Female guest researcher from Shanghai Jiao University works for 10 months in Project 3

7. Recruiting

Recruiting of PhD students is difficult as expected. However, we managed to engage eight within 2007, of which two are female and six are Norwegian, which we consider to be acceptable. In addition come a female postdoc from Malaysia (Project 1).

In 2007 SINTEF Building and Infrastructure has employed two researchers who will work in COIN projects, as well as a secretary in a 50 % position to support the administration of the centre.

8. Accounts

The accumulated cost in 2007 was NOK 26 mill, of which NOK 18 mill was spent by the host (SINTEF) and its research partner (NTNU), and NOK 8 mill by the industry partners. The financing was NOK 10.5 in cash, of which 7.4 mill. was from the Research Council of Norway, and NOK 15.5 mill was in-kind from the partners. All partners, except two (one of them being late participant), increased their in-kind contribution beyond the amount given in the agreement.

9. Publications

COIN has produced nearly 40 publications in 2007, divided as shown below. In addition we have had a number of oral presentations of COIN, nationally and one abroad; at the Nordic Concrete Day in Stockholm.

9.1 Scientific Papers

In journals

- Microstructure and performance of energetically modified cement

In conferences

- Mechanochemical technology: Synthesis of Energetically Modified Cements
- Calcium Nitrate as a Multifunctional Concrete Admixture
- Lightweight Aggregate Fines as Pozzolanic Additive for High Performance Concrete
- Silica Fume in High Quality Concrete – A review of mechanism and Performance
- Properties of cement kiln dust (CKD) and use in cementitious materials an overview
- Principle and performance latex modified mortars

9.2 Industrial articles

In journals

- Enige om COIN fokus - Byggeindustrien
- Go for COIN - Byggeindustrien
- COIN Visjon og virkelighet - Cement nå

In conferences

- COINS barndom hvordan var den ? - Norsk Betongdag
- COIN - Attraktive betongbygg - SINTEF/NTNU Informasjonsdag
- Fobedrede konstruksjonsteknikker - SINTEF/NTNU Informasjonsdag
- Nyskapende konstruksjonsløsningner - SINTEF/NTNU Informasjonsdag
- Operasjonell levetidsdesign - SINTEF/NTNU Informasjonsdag

9.3 Popular scientific articles

In journals

- Betongrevolusjon - Vegen og vi
- Styrkeløft for betong - Temaavis i Dagens Næringsliv
- CONCRETE Strickes Back – Hard - Tellus
- Betongmiljøet slår tilbake - Forskning

9.4 Reports

P1 Advanced cementing materials

- Principles of making cement with reduced CO_2 - emission
- Making cement with less clinker content
- Effect of mineralizers in cement production
- Separate grinding versus intergrinding
- Ternary blend cements with fly ash and Limestone: Part 1
- Ternary blend cements with fly ash and Limestone: Part 2
- Accelerating admixtures for concrete
- Retarding admixtures for concrete
- Reduced cracking by modifying matrix with admixtures or additives
- Influence of fibers on cracking due to plastic and drying shrinkage
- Reduced cracking by internal curing of concrete
- "Alternative pozzolans" as supplementary cementitious materials in concrete

P2 Improved construction technology

- Quality of concrete surfaces
- Concrete workability and fibre content

P3 Innovative construction concepts

- Ice abrasion data on concrete structures - an overview

P4 Service life design

- Critical chloride content

P5 Energy efficiency comfort

- Review of Thermal Mass Concepts