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POSSIBLE USE OF FERROCEMENT IN ROMANIA

BY

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Abstract. The present paper will give a review of former and new developments in the research of ferrocement as a construction material. Even if in the ’80…’90 the focus in using the ferrocement for structural elements was high, nowadays it is almost forgotten, especially in Romania. At the same time we need economical, sustainable and efficient buildings to keep up with the new environmental and social challenges. Several types of constructions are presented in this paper to show the applicability of this material in our country. One of the main characteristic is the small dimensions so the rigidity of the ferrocement element comes from the designed shape and in the cases presented here is the dome shape.

Key words: dome; storage; biogasplant; school; low cost housing.

1. Ferrocement

The ferrocement was invented by Joseph Louis Lambot in 1848, but it was used for construction elements in the beginning of the 19th century by Pier

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Luigi Nervi , a famous Italian designer who wanted to have a homogeneous and efficient material for his complex architectural shapes. Ferrocement is a type of thin wall reinforced concrete commonly realized of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size steel wire mesh. He thought that by increasing the steel percentage would be possible to create a new material characterized by a higher strength and especially with a symmetric behavior in tension and in compression (Di Prisco & Ferrara, 2011).

2. Materials Used

The term *ferrocement* is most commonly a mixture of Portland cement and sand applied over layers of woven or expanded steel mesh and closely spaced small-diameter steel rods rebar. For optimum performance, steel should be rust-treated, (galvanized) or stainless steel. The water/cement ratio is 0.40…0.45 and the maximum dimension for the course is 8 mm. The choice for the type of concrete mixture is governed by strength and durability demands. The placement method used is either spray or manual applying just like in the Fig 1.

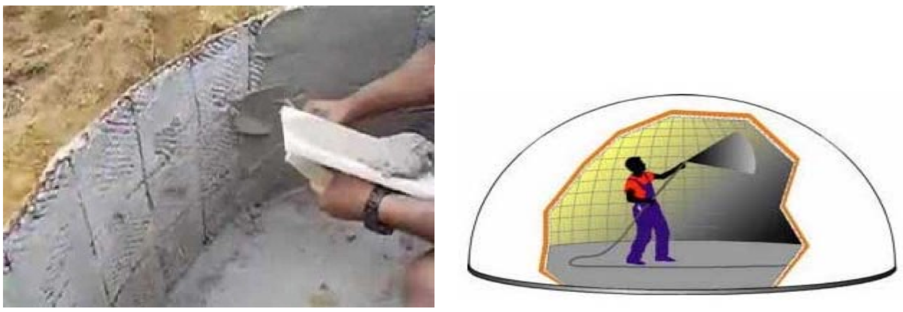

Fig. 1 – Placement methods: manual and shotcrete.

Using the ferrocement it's a big advancement in form-making, allowing the elimination of the wooden planking, which had been responsible for limiting forms to rectilinear shapes. Even though timber is renewable, building wooden formwork is labor intensive, and the forms are usually discarded after a single use. The thickness of a ferrocement element is between 2 cm and 10 cm and that's why the rigidity comes from the designed shape. This small dimensions bring the advantage of having light structures with a minimum of material used. One of the best forms to use are the shells with positive gaussian curvature that are similar to the shapes of domes found in nature, such as the egg or the shells.

3. Domes

Domes are types of thin shells in the form of surface of revolution, which serve primarily as roof structures. A surface of revolution is obtained by the rotation of a plane curve about an axis lying in the plane of the curve. Domes can be classified based on type of curvature, boundary shape and boundary constraints. There are several types of domes that can be categorized based on their shapes. Spherical domes are in the shape of sphere and transfer the loads into uniform load over the dome surface. Some domes are in the shape of parabola and are called paraboloidal shells or domes. Ellipsoidal domes are the result of revolution of ellipses and they have elliptic shapes. Another shape of dome that is considered as a recent innovation is called geodesic dome that is known to be a tension/compression type of structure . Also, the study of dynamic behavior of domes becomes important and several researchers have studied the free vibration response of the shells.

An alternative to the traditional buildings materials the ferrocement has relatively good strength and resistance to impact and when used in house construction in developing countries, it can provide better resistance to fire, earthquake, and corrosion than traditional materials, such as wood, adobe and stone masonry. A model for low cost rural houses with shell roof, a dome school and an industrial storage dome are presented in this paper. The research study demonstrated that the use of thin shell roof render higher rigidity of the structure and requires less contruction material. Dome structures are thin-wall reinforced concrete shell structures capable of providing safe shelters for people in the areas with hurricanes and earthquakes. These structures use a minimum amount of material for the area to cover, they are easy to erect since no form work is required, and, more importantly, they are heat efficient because 5…10 cm of polyurethane foam is applied on the interior of the inflatable membrane.

3.1. Building a Dome

The steps involved in building a monolithic dome are unlike those in any other type of concrete construction. The foundation consists of a concrete ring and after the footprint is leveled the concrete walls are made, the attachement of the airform is the next step and all the large equipment and materials used next must be placed within the foundation and covered. The airform is now unrolled, unfolded and connected to an air tube and the inflation starts using giants blowers fans. The fans continue running throughout the construction of the dome. A layer of foam is sprayed on the inside of the membrane and then the rebar is installed. Steel reinforcing bars are attached to the foam using a specially engineered layout of hoops (horizontal) and vertical steel bars. One or two layers of steel mesh will cover this rebarbs. The final step in building a monolithic dome is the application of shotcrete to the interior surface of the structure. The thickness of the concrete is of 7...10 cm. Once the shotcrete has been applied and it's hard, the blowers fans are shut off and the dome is complete. This type of structure has more advantages. The energy efficiency of the dome houses has been a major reason in choosing to have this type of building. The domes are typically 50% less expensive to heat and cool than traditional buildings. This means that the building requires 50% less heating and venting equipment and therefore about a third less electrical equipment than a similar size conventional building. The construction time is very short, around two months, not being delayed at all by weather conditions because all the work and the equipment are inside of the structure.

4. Possible Use of Dome-Structures in Romania

4.1. Storage Domes

Market and climate conditions have a large effect on the type and capacity of required storage so the trend is to provide large capacity structures. Most production facilities have a high and low demand season and during the low demand period material must be stored to supplement production during the peak demand period. The dome has always been one of the most practical solutions for storing large volumes of fly ash, cement, cereals and other industrial bulk materials. Dome storage is becoming increasingly popular in the cement industry. This is especially so for cement distribution terminals where the combination of investment and operational costs of domes often offers the most suitable alternative. Moreover, to achieve sufficient redundancy, two smaller domes are recommended, each to handle half of the storage capacity, rather than one large dome.

Fig. 2 – Cement storage in Lagerdorf, Germany.

The majority of installations are in North America including most of the domes used to store fly ash. The largest concrete storage dome for cement is in

Lagerdorf, Germany (Fig 2). Properly, constructed concrete domes are strong enough for materials to be piled against the walls. They can also support heavy conveyor loads without any internal supports. Large front end loaders routinely scoop up against the walls of concrete domes without any concern about damaging the structure. Concrete domes are cost competitive , especially in large capacities. This is due in part to the fact that spherical shaped domes involve less surface area than other shaped structures, thus less materials are required. Since most of the materials needed for dome construction are locally available almost everywhere, the imported item are at minimum.

4.2. School Domes

The majority of this type of schools are in North America but the advantages are remarkable and makes them proper to be used anywhere else in the world. An example of this kind of structure is presented in Fig. 3.

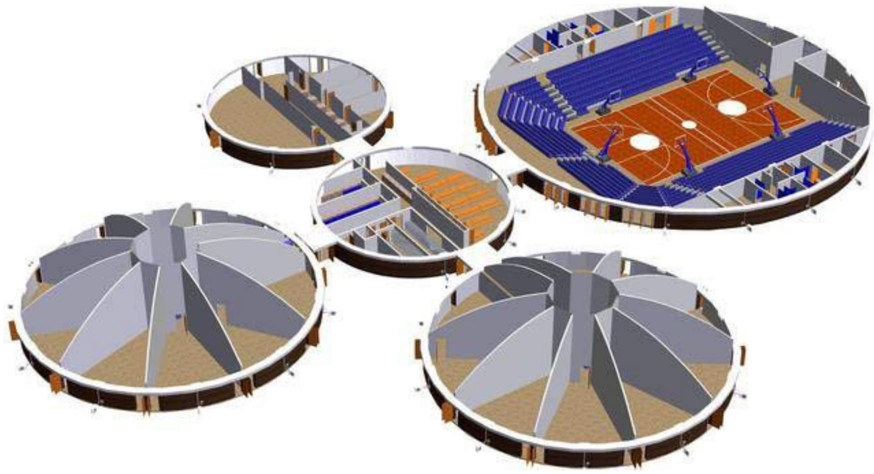

Fig. 3 – The layout of a dome-school in USA.

The superiority of domes as roofs is in their stiffness and strength that they stand without the support of columns. Domes are very strong and durable and in a realistic situation would probably still be standing "when all conventional structures had failed". Domes are among the most efficient structures available, especially as roof structures. As a roof structure, the main force that a dome bears is its own weight. For investigating the dynamic response of domes to applied loads, the variables that affect their behavior are cut down to a limited number and are mainly dome shape, thickness, span length, and height. However the complexity of their analysis, design and fabrication sometimes limit their use. These structures are well suited for the areas with a high risk of natural disaster and the third world countries. Depending on the quality of construction and the climate of its location, this buildings may pay for themselves with almost zero maintenance and lower insurance requirements.

4.3. Biogas Plant Domes

This ferrocement concrete information can be used to make concrete biogas digesters and gas storage tanks. This information can also be used for the construction of water tanks, grain storage tanks, or for almost any construction project that needs strong concrete walls. The wire distributes the load throughout the concrete, preventing the force of the load from concentrating in planes of weakness which would lead to early failure. A section throught a gas plant is presented in Fig.4

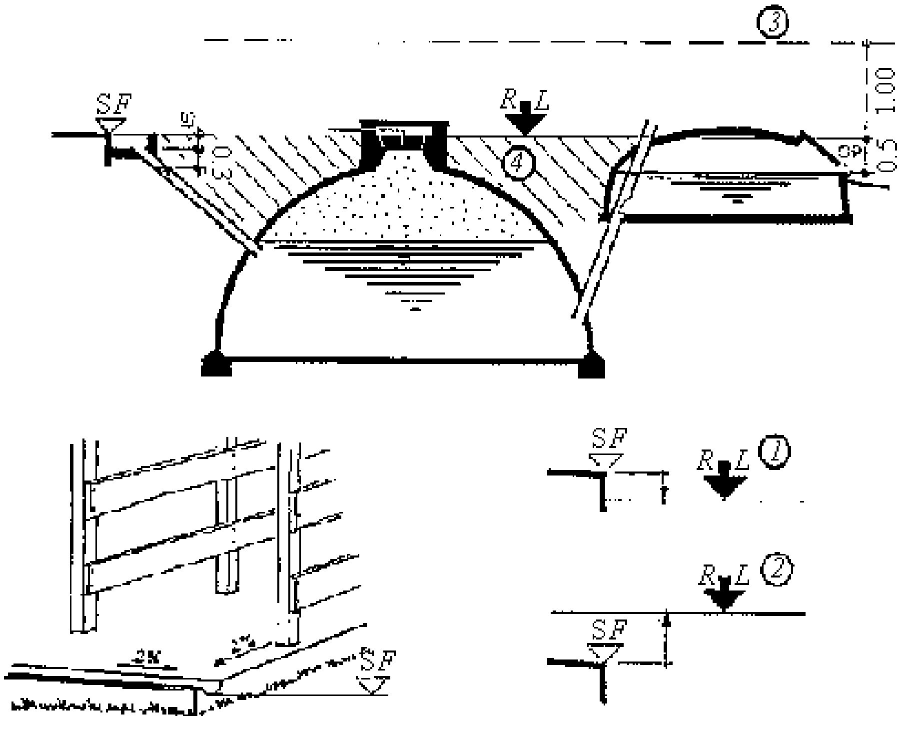

Fig. 4 – Section through a rural biogas plant.

A gasplant of a rural biogas unit is standardized and preferably a fixed dome plant. The size of the plant depends on the substrate available. In practice its volume is chosen according to the number of cattles or pigs and their stabling. The standard fixed dome plant has a half-bowl spherical shape with flat bottom and a top opening. The outer walls rest on a foundation ring beam. The floor has no static function. The upper part of the sphere is separated from the lower part by a joint, called the *weak ring*. Gas tightness of the upper part is achieved by a crack-free structure and a gas-tight inner surface plaster. The inlet pipe is connected to the spot of dung disposal in the stable. The outlet pipe connects the digester with an expansion chamber of reduced spherical shape. The overflow of the expansion chamber – really the final outlet of the gasplant – leads to the slurry disposal system, *i.e.* the distribution channel, storage tank or compost pit. It should not be in areas where heavy machinery move frequently. Biogas plants are not meant to be a playground, still they should be safe for children and animals. A preparation for building this kind of dome is presented in Fig. 5.

Fig. 5 – Ferrocement dome for biogas plant.

Some biogas quick facts are: biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes.

4.4. Dome Houses

Dome shape minimizes surface area per volume, meaning less heat leakage, so lower heating/cooling costs. The dome houses become the highlights in USA after hurricane Ivan hit Florida in 2004 and the only house that was not distroyed by the high winds was a dome house in Pensacola Beach. From an architectural point of view the dome houses have an organic look inspired by the shells in the nature and they are quite challenging to decorate inside with traditional furniture. An example of a small house is presented in Fig. 6

Fig. 6 – Ferrocement dome house.

5. Conclusions

The disadvantage of ferro concrete construction is the labor intensive nature of it, which makes it expensive for industrial application in the western world but suitable for Romania. This means cheap local work can be used, jobs can be created and all the materials are easy to get again locally. The technique of constructing with ferrocement can be learned in some course trainings and the design of it is already presented in „Cod de proiectare şi execuţie a elementelor din ferociment" elaborated by the Technical University of Cluj-Napoca.

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POSIBILITATEA UTILIZĂRII FEROCIMENTULUI ÎN ROMÂNIA

(Rezumat)

Se prezintă evoluţia şi stadiul actual al cercetărilor referitoare la ferociment, material care a avut parte de un interes deosebit în ani '80…'90 în alte ţări cât şi în

România dar care acum este complet uitat. Nevoia de adaptare la noile condiţii climatice şi sociale ne obligă să proiectăm clădiri eficiente energetic şi sustenabile. Elementele din ferociment sunt subţiri şi îşi obţin rigiditatea din forma lor, astfel că forma de dom este cea aleasă pentru tipurile de construcţii prezentate ca aplicabilitate a ferocimentului în România.