# USING FERROCEMENT IN CONSTRUCTION

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**Abstract:** *The paper presents some applications and considerations about concrete with ferrocement. Ferrocement is a cheap and quality material for construction, with very large scale applications, which can become an alternative material in the design and implementation of buildings. Ferrocement is the material that can be used for thin wall elements and that can be calculated based on thin surface theory. Surfaces can be geometrically shaped more easily than any other building material.*

**Key words:** *ferrocement, thin-walled, environment.*

## 1. Introduction

The ferrocement is a construction material with a good quality-price ratio, with a very large scale application and enables the construction elements with a virtually unlimited geometry, this material can become a worthy alternative considered in the design and implementation of construction. The ferrocement is a building material made of thin cement slabs reinforced with thin mesh steel.

The concrete with ferrocement can be tempting materials for building due to the simplicity of achievement, as well behaviour favourable to various stresses compared to reinforced concrete. The ferrocement is a composite material that can be performed for various elements of building and can successfully replace diverse traditional building materials as: reinforced concrete, wood, brick, etc. [1]

Using of ferrocement in prefabricated elements can reduce the human role (human error) by searching the solutions for automatization, such as: carcass reinforcement, concrete formwork, casting etc.

Quality of ferrocement works are assured because the components are manufactured on machinery set up and execution time at work site is less. Cost of maintenance is low. This material has come into widespread use only in construction in the last two decades.

Ferrocement is a particular type of concrete used in thin-walled (10-40 mm) made of reinforced cement nets continuous rows of small diameter wires, arranged at short distances between them as shown in Figure 1. The mesh can be made of steel wires, glass fibbers fabrics, polypropylene fabrics or natural fabrics (bamboo and jute). Ferrocement has better strength, ductility and durability than reinforced concrete. [3]

Due to these good characteristics physics - mechanicals, ferrocement has a wide range of applications, allows building elements with unlimited geometry, it can be used in the

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Fig. 1. *Constructive method*

following areas of civil, industrial and agricultural: roofs made of thin blades; as a substitute for heat insulation in roof framing and roof deck Figure 8; structural elements of the framework; precast panels for walls and floors Figure 14; the panels fences; pavers and pavements; single-family houses Figures 2, 7, 9, 10, 12; silos; structural elements: columns, beams, walls, thin-walls; animal shelters; floorings; pools of water treatment; pools or water tanks Figure 3; adduction pipe; drains; bracket panels to capture solar energy; maritime constructions etc.



Fig. 2. *House under construction*



Fig. 3. *Water tank under construction*

## 2. Thoughts on how thin walls are calculated

Thin-walled elements are commonly found in building structures, bridges or ships, and their use is justified due to low consumption of material, so very economical. [6]

The cross section of a thin-walled bar is developed along an axis called the median axis of the Figure 4. At any point or the median axis it divides in half the thickness "t" of the bar wall measured on the median axis. In thin-walled bars, the wall thickness "t" is reduced compared to the median axis length, as well as to any of the overall dimensions of the section (width, length or height), approximately: $t/(l1,l2,l3)<1/10$.
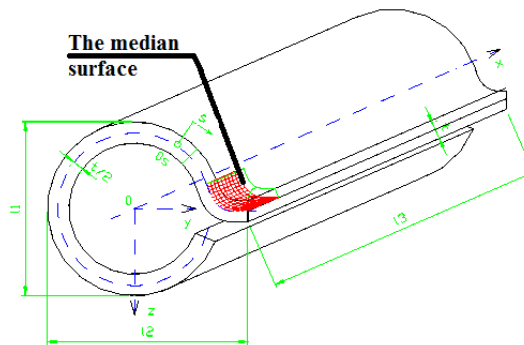


Fig. 4. *The section of a thin-walled bar*

The geometric location of the centre of gravity of the cross section is the axis of the bar. The prismatic bars have the axis, a right, and any cross section is normal to the axis and is constant along the bar. By translating the median axis of the section along the bar, the median axis of the thin-walled bar is obtained.

The median axis can be an open curve in this case the bar is called: simply connected (Figure 5: a, b, c, d), or a closed curve, when the bar is called: with section closed or double connected (Figure 5: e, f), multiconnected (Figure 5: g).
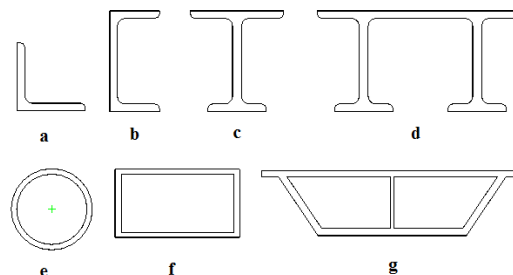


Fig. 5. *Examples of thin wall elements*

By plotting the bar to a cartesian system (Figure 4) with the 0x axis superimposed over the axis of the bar and the axes 0y and 0z in the plane of the cross section, the geometry of the prismatic thin walls bars is completely determined by the equation of the median

axis in the cross section and by the law of the thickness variation "t". The most commonly used are the parametric equations given by the arc s, measured from a specified origin 0s:

$$y = y(s), \; z = z(s), \; t = t(s) \tag{1}$$

The calculation for such types of single connected or double connected bares is based on V.Z. Vlasov. For the double connected bares, the "f" deformation function is additionally added.

The theory of V.Z. Vlasov admits that:

- the material from which the element is made is isotropic, homogeneous, and the laws of Hooke and Bernoulli are valid;

- the tangential unitary forces of the free turning, vary linearly over the wall thickness;

- in the simply connected bares, deformations at the level of the median section of the section are omitted;

- the contour of the cross-section is indeformable in its plane.

The inderformability transverse of bars is ensured by transversal stiffeners. Outside its plane, the cross section has a low stiffness so deformations and longitudinal displacements can occur.

For double connected thin wall elements, sectoral tangential unitary efforts are close to the same order of magnitude as the tangential unitary forces of torsion and greatly influence the deformation value. To take this into consideration, the "f" deformation function is introduced, which depends on the current section of the bar length and characterizes the intensity of stress of this section. The deformation function is determined by a system of two differential equations linking the moment of twisting Mrz, the twisting angle φ (z) and the deformation function f (z). The calculation of thin-walled bars with double connected is added:

- the sectoral normal unitary efforts are proportional to the sectoral coordinate and the second derivative of the f (z) deformation function;

- the unitary stresses sectoral tangents are constant on the wall thickness.

Under the action of torsion, bars that do not have a circular or annular section, the cross section is deplanated (Figure 6, a). Deplanation is more evident when a bare, simply connected bar with concentrated forces parallel to the axis of the bar is required. For example, consider a thin-walled rod having the cross section in the shape of "I" (Figure 6: b). On this bar acts two forces at the corners of the section, parallel to the axis, which are reduced to the center of gravity of the section at an axial load N = 2P. It can be seen that in the "I" thin-walled bar, applying the two forces, they cause bending of the soles over the entire length of the bar and, at the same time, due to the displacements in opposite directions of the soles, the torsion of the bar, accompanied by the deplanation.

According to this example, and similar ones, it can be highlighted that the flat section hypothesis for thin-walled bars cannot be used for any kind of load. At the same time, the principle of Saint-Venant's local effect is no longer valid. The calculation should be based on sectoral characteristics.
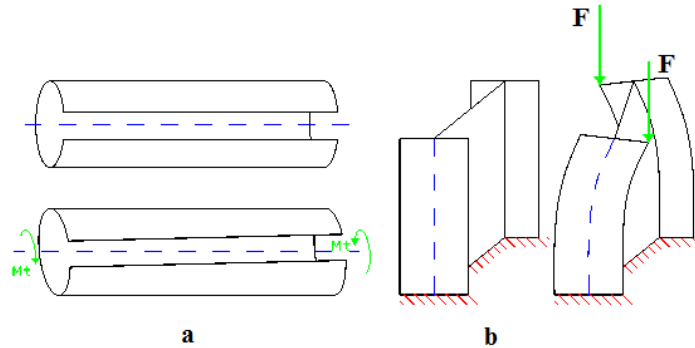
Fig. 6. *Deplanation under the action of: a) torsion b) two concentrated forces*

## 3. Using of Ferrocement at Various Thin Building Elements

The construction illustrated in Figure 7 is a house in "harmony with our planet" or called organic buildings. The build-up was based on concrete spraying technology, i.e. a torcreating procedure used predominantly in industrial constructions such as tunnels and bridges.



Fig. 7. *Houses buried in harmony with the earth buried*

The construction of Figure 8 has a saddle shaped roof or a hyperbolic paraboloid. The roof is an emulation of 10 cm thick thin concrete webs on large surfaces. The saddle (hyperbolic paraboloid) is used in public and industrial constructions as a model for roofs (eg Predeal railway station), since this surface can be made of rectilinear elements with maximum efficiency.

In Figures 9, 10 and 11 there are two similar constructions, as execution technology, built far away distances from each another. All the exterior and interior compartments have been used as shown in Figure 1, the ferrocement elements having in the middle layer polystyrene. The material used proved to be a good thermal insulator as well as very cheap compared to any other classical materials. [5] It is worth noting that the construction in Romania - Brasov has several levels. The shape close to the sphere has

brought an increase in efficiency in what concerns the inner forces in the material, the bending moments being approximately equal to zero.



Fig. 8. *Parabolic hyperboloid roof (saddle)*



Fig. 9. *The spherical house from Brasov*



Fig. 10. *The spherical house from Tailanda*



Fig. 11. *Inside the house from Thailand*

The house from Figures 12 and 13 is in harmony with the environment and it is another organic building from Switzerland. It is an eco-friendly and thermally efficient construction technology. The building is based on a structure in metal springs over which the concrete is sprayed. Over the concrete are applied the waterproofing membranes, and over them follows the layer of soil, which has the thermal insulation and provides the perfect support for the vegetation that bears the structure. Natural lighting is done through front window and domed luminaires, so that the environment is comfortable for this view [2, 4, 9].



Fig. 12. *Organic buildings from Switzerland*



Fig. 13. *Inside the house from Switzerland*

In Figure 14 can be seen an external closure in a waves shape made on a support material also from ferrocement.



Fig. 14. *Surface of corrugated closing*

The use of ferrocement for building up floors is an efficiently solution in many situations. As well, the utilization of ferrocement for the rehabilitation of building elements is a possible solution and, in some cases, it appears as the only alternative to the solutions of rehabilitation currently applied (ex. for elements to which severe restriction in what concerns the cracking are imposed or for those elements having an architectural distinguished form) [6,7,9].

## 4. Final Conclusions

Definition of the ferrocement adopted by the majority of the specialists are: "The ferrocement is a type of reinforced concrete in thin elements, currently constituted by micro-concrete of hydraulic cement, reinforced with thick layers of continuous netting, in wire, with a relatively small diameter. The net may be metallic or in other materials ".

The mesh can be made of steel wires, glass fibbers fabrics, polypropylene fabrics or natural fabrics (bamboo and jute). Ferrocement has better strength, ductility and durability than reinforced concrete. Ferrocement can be used in any kind of civil, industrial and agricultural construction under normal exterior loads, moderate openings and under any geometrical shape of the surface. [8]

The advantages of using ferrocement instead reinforced concrete result from ferrocement particularities: small thickness of the element (10 … 50mm), uniformly spread of reinforcement, the reduced cracking process, a better ductility and a high resistance to impact.

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