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CONSTRUCŢII. ARHITECTURĂ

RETAINING WALLS MADE OF PRECAST CYLINDRICAL VAULTS

BY

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Retaining walls are a large category of engineering structures of multiple uses, having an essential safety ensuring role. The structural systems are varied because the situations and requirements derived from both site conditions and other criteria are varied.

The paper enlarges upon retaining walls systems that use an outstanding amount of precast units and multiple cylindrical vault type structural systems supported by abutments [1], [2]. The paper proposes extending the structural system to retaining walls and develops certain specific issues. Some considerations regarding stuctural design are made.

1. Introduction

Retaining walls are structures of great practical utility. They are included mainly in the category of safety ensuring systems. These walls are widely used on the tracks of traffic ways that cross relatively uneven areas, along water streams, especially when the rivers pass through urban areas where regulation works may be necessary in case landslides need to be controlled. Retaining walls may be also found in certain built-up areas developed on hills or along the rivers, in the vicinty of works of art, *e.g.* bridges.

The erection of such structures requires a large amount of materials as well as workforce, to say nothing of the additional works done on the building sites. The technologies that use precast units in these stuctures enable a diminution of the wet works, of forms and, sometimes, even of displacements, as well as an easier operation accompanied by a more efficient control of precast units quality.

Under such conditions, the designing of these retaining systems differs from that of massive masonry walls. A solution, still in use but insufficiently developed, is that of erecting retaining walls with abutments. Essentially, in these systems, the ground thrust and other cumulative effects are transmitted to some spaced elements – the abutments. More in-depth analyses demonstrate that these abutments can be built in such a way as to interact with soil masses or rocks, with favourable effects on safety ensuring.

2. Precast Units

The precast units (blocks) are thus designed so as, when cast in place, to produce a wedging without other additional materials and means [3], [4].

The first member (Fig. 1 *a*) is shaped like two frustums of pyramid with rectangular bases, the smaller ones being extended to form one unit (Figs. 1 *b*, *c*).

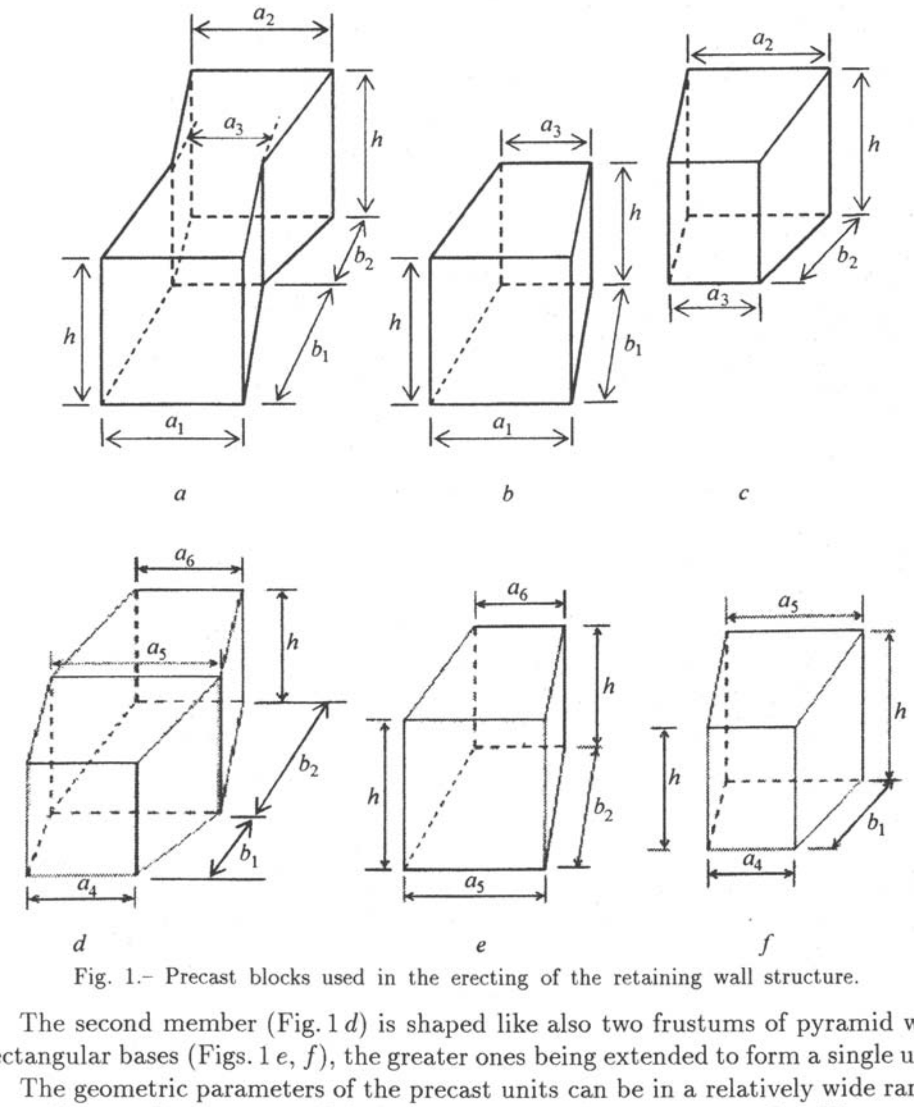


Fig. 1.- Precast blocks used in the erecting of the retaining wall structure.

The second member (Fig. 1 *d*) is shaped like also two frustums of pyramid with rectangular bases (Figs. 1 *e*, *f*), the greater ones being extended to form a single unit.

The geometric parameters of the precast units can be in a relatively wide range, depending on the geometry of the structure, strength requirements, handling means when placed, coupling mode (mortars, additives, etc.). In sizing up, all dimensions can be expressed in relation to a single parameter, λ. An example, tested on models

[3], [5], without being restrictive, may be:

$$a_1 = \lambda, \quad a_2 = (1.1...1.2)\lambda, \quad a_3 = (0.6...0.7)\lambda, \quad a_4 = (0.5...0.8)\lambda,$$

$$a_5 = (1.5...2.0)\lambda, \quad a_6 = (0.6...1.0)\lambda, \tag{1}$$

$$b_1 = (1.0...1.5)\lambda, \quad b_2 = (1.0...1.3)\lambda; \quad h = (0.8...2.0)\lambda.$$

Practically, these values have some geometrical constraints.

More complex decisions concerning the sizing of the precast blocks can be taken during structural design work, which depends on the specific site conditions and the envisaged structural system [6]. The paper will focus on the multiple vault abutments system, which has proved to be very efficient.

The precast units may be composed of :

a) concrete (heavy), grades 15...25 made up of Portland cement ;

b) heavy concrete, grades 15...30 with hydraulic cements and additives, especially where water is present (rivers, sea) ;

c) concrete of light-weight aggregates with common or special cements, depending on the aggregates used, when the precast structure does not contribute with its dead weight to ensure the stability of the retaining wall-ground system.

The precast unit in Figs. 1 *a* and *d* may be used alone in making the structure or in the other combination, for example members *a* and *e*, or *a* and *f*.

It is worth mentioning that the precast units may be made using the same form-works, from the units *a* and *d*, by placing the metal or glass plates for delimiting their side.

Likewise, introducing the plate in the central section of element *a* the elements *e* and *f* were obtained.

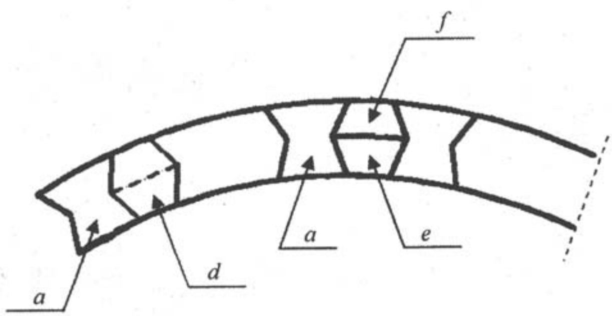


Fig. 2.- Precasting procedures using a single formwork system.

In practice, all types of units described so far can be erected in one formwork by creating separation joints, depending on the requirements of the structural system (Fig. 2).

All the described units, or parts of units may be made up of stone by using performant stone cutting equipment, in which case aesthetic shapes are aimed at.

Similar units for certain retaining walls may be made from special ceramics. Where the architectural design requires it, functional and aesthetic details may be considered.

3. Structures for Precast Retaining Walls

Further on, mention will be made of the vault-shaped retaining walls made up of precast members supported on *in situ* cast abutments (Fig. 3).

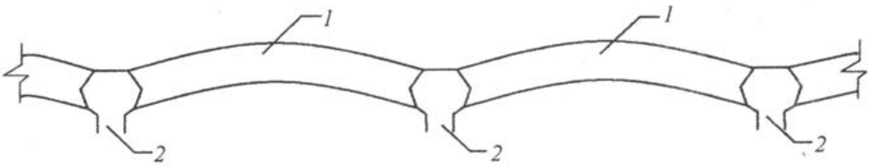


Fig. 3.– Plan view of the retaining wall: *1* – vaults; *2* – abutments.

The disposition in plan of the precast units can be seen in Figs. 4 *a*, *b*, *c*, *d*, *e*.

The mounting of the precast units may be done with high grade cement mortar and plastifying agents that increase their ductility, adhesiveness, and shear strength, as well as by using specific adhesives instead of mortar.

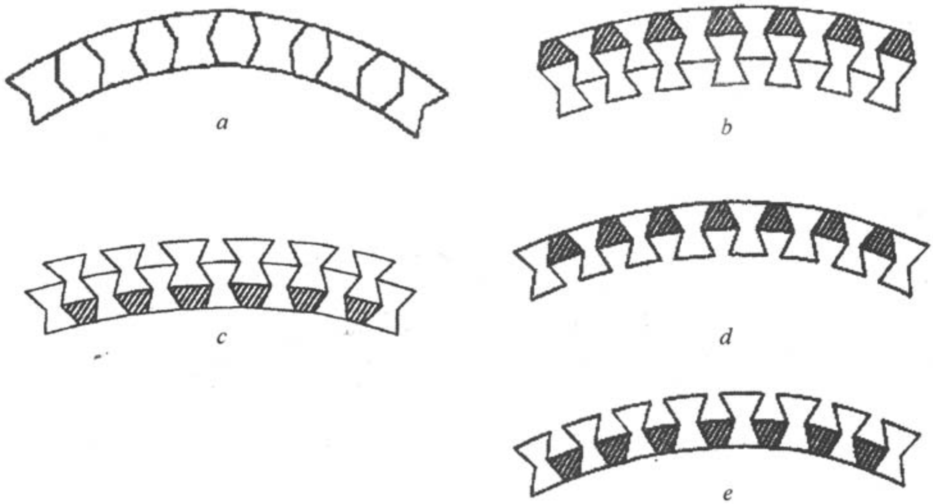


Fig. 4.– Plan view of the vault-shaped disposition of the precast units.

If the retaining walls have a great height, splayed foundations may be erected under the vaults, their hardening being achieved by *in situ* casting of concrete after assembling, which may take several shapes, as presented in Fig. 5.

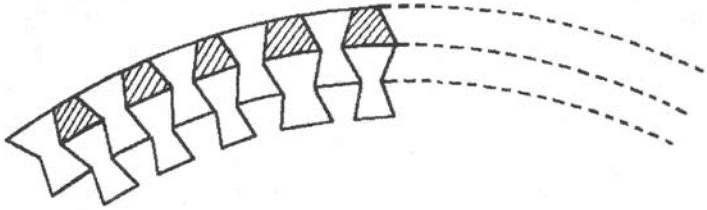
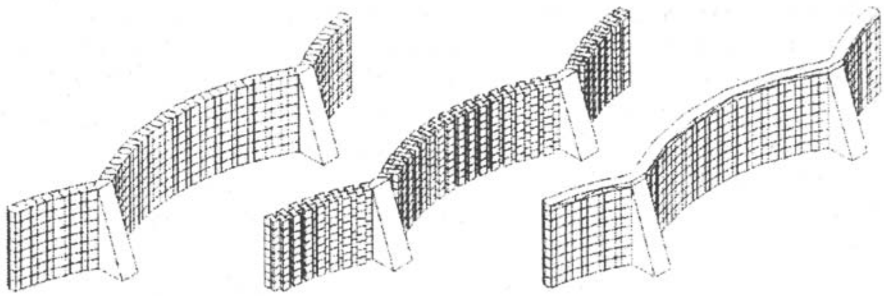


Fig. 5.– *In situ* casting works.

The concrete may be also reinforced along the vertical, while the reinforcement may be anchored to the foundation.

In certain zones, the retaining walls have the characteristics of works of art, and the crowns may be correspondingly treated (Figs. 6 *a*, *b*, *c*). Other architectural elements can be attached, as well, and the abutments are included in this aesthetic conception.



a *b* *c*

Fig. 6.– The retaining walls as works of art.

The sizes of the precast units may vary, depending on the assembling technology, the handling means and, obviously, on the strength and stability characteristics required from the works. In the areas with reduced accessibility, simple precast units may be made and they can be assembled by means of simple plant (*e.g.* a pulley), or manually. Some precast units can be provided with horizontal voids which are meant to drain the water collected behind the wall.

At the same time, girdles meant to link the vaults and interact with the abutments are made on the crown. They play a protective role, of channeling the rain water, and, if adequately finished, contribute to the aesthetic effect of the stucture as a whole.

4. Considerations on the Structural System and Assembling Methods

The takeover of the main stresses from ground pressure and the possible overloads, as static loads, by the multiple vaults, has been efficient. Up to heights of 6...8 m, the vaults can have a constant thickness. At greater heights and important overloads, *e.g.*, generated by traffic, the vaults can be designed to have variable thickness, in steps. Several solutions are feasible: one examples is presented in the case in Fig. 7.

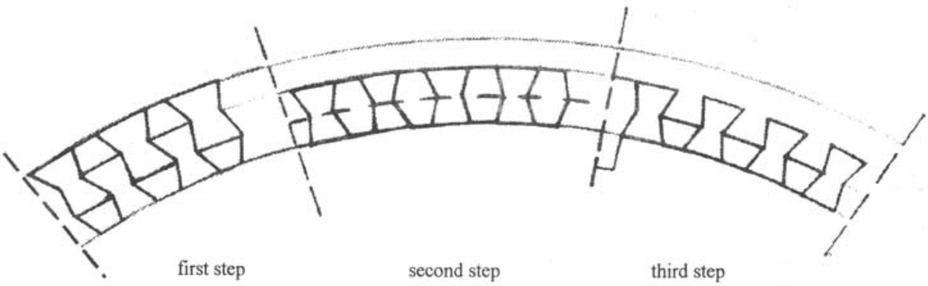


Fig. 7.– A retaining wall of a thickness varying in three steps.

This becomes a retaining wall of a thickness varying in three steps. The height of the wall, H, is divided in three equal parts, $H/3$ each. From the basis to the $H/3$, first step, the precast unit, a, e and f, are used, while from $H/3$ to $2H/3$ – second step – the precast units a and d are used. On the last third of the height (third step), remains units a and e.

This arrangement, shown in Fig. 7, is an economical system both in terms of materials consumption, workforce and structural strength.

5. Some Problems Regarding the Design

We consider, firstly, that the wall have not the displacements. The vertical pressure and the lateral pressure, from the dead weight of the soil are, respectively,

$$p_\nu = \sigma_z = \gamma h \tag{2}$$

and

$$p_h = \sigma_h = \frac{\nu_0}{1-\nu_0}\gamma h = K_0\gamma h, \tag{3}$$

where: γ is the unit weight of the soil; ν_0 – Poisson ratio of the soil as elastic bodies; K_0 – the coefficient of lateral pressure of soil; h – the depth.

When a continuous uniformely distributed load, q, acts on the surface of soil, the pressure is:

$$p_h = K_0(\gamma h + q). \tag{4}$$

The direction of the pressures, σ_h, are the same of the radii of cylindrical wall.
The axial effort from the cylindrical wall produced by p_h is

$$N = Rp_h = RK_0(\gamma h + q), \tag{5}$$

with R – the cylindrical radius.

Due to the arch effect, the soil pressures generates forces that self balance on the abutment as well as forces in the vertical plan of the abutments, being taken over by these (Fig. 8).

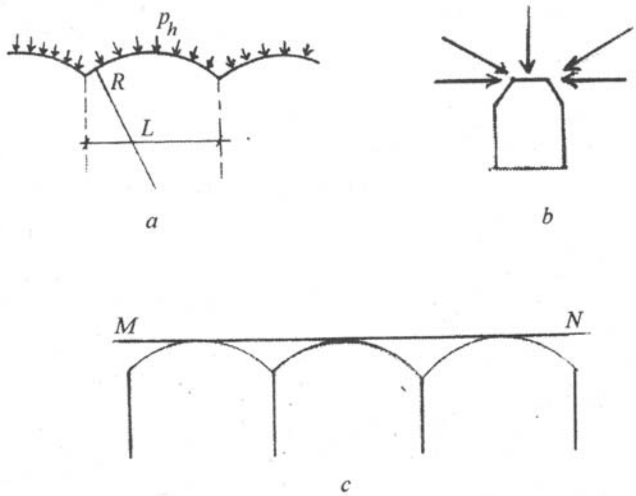


Fig. 8.- a – The direction pressure of the soil; b – the arch effect; c – the plane of the pressure.

If the retaining wall have a displacement, the active pressures of the soil may be evaluated by Rankine method, considering the pressures on the plane MN (Fig. 8 c).

6. Conclusions

The vault-shaped retaining walls made up of precast units, initially designed for filter dams [2], adjusted and adequately developed, have several merits, of which mention can be made of:

a) manufacturing of precast units in workshops, which ensures the high quality of the products;

b) savings in materials: forms and concretes, compared to the current solutions;

c) precast unit shapes and the manner of placing them ensure an adequate balance and a high strength, as well as a higher productivity, as compared to the wholly cast *in situ* retaining walls;

d) large possibilities to ensure the stability of the structure, due both to the arch effect and the transmission of stresses to the abutments;

e) the retaining walls, by their shapes and the details that can be associated to, belong to the works of art with a significant aesthetic value;

f) adaptability to varied relief shapes.

By designing precast retaining walls shaped as vaults supported on abutments and taking account of the specific locations, various other merits of these systems can be enhanced.

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ZIDURI DE SPRIJIN CA BOLŢI CILINDRICE PREFABRICATE

(Rezumat)

Zidurile de sprijin reprezintă o categorie largă de structuri inginereşti cu multiple utilizări, având ca rol esenţial siguranţa. Sistemele structurale sunt variate deoarece condiţiile şi cerinţele derivate atât din condiţiile naturale cât şi din alte criterii sunt variate.

Se detaliază o serie de probleme relative la sistemele de ziduri de sprijin care utilizează o cantitate însemnată de blocuri prefabricate pentru realizarea de sisteme structurale sub formă de bolţi cilindrice multiple, rezemate pe contraforturi [1], [2]. Se propune extinderea acestui sistem structural la ziduri de sprijin şi se dezvoltă unele aspecte specifice.

Sunt făcute unele consideraţii cu privire la proiectarea structurală.