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Using Precast R.C in Cellular Dam Construction

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ABSTRACT

In concrete dams on earth foundations, 50% to 60% of concrete works as ballast creating the weight of structure necessary for ensuring stability against sliding . For this purpose, precast– monolithic cellular structures have been developed, which comprise longitudinal and transversal walls forming the carcass .the pre-cast concreat units with dimintions 2-6m long, 0.5-0.7m height, 0.07-0.015m thickness. The compartments of the carcass are filled with soil material . such cellular structures are used for constructing small head dams (up to 10 to15 m high) and wing walls in medium to low head dams as indicated in figure (1) .

Keywords: *concrete, dam construction*

1. INTRODUCTION

The first dam for which there are reliable records was built on the Nile River sometime before 4000 B.C. It was used to divert the Nile and provide a site for the ancient city of Memphis .The oldest dam still in use is the Almanza Dam in Spain, that was constructed in the sixteenth century.

With the passage of time materials and methods of construction have improved, making possible the erection of such large dams as the Rogun Dam, which is being constructed in the USSR on the Vaksh river near the border of Afghanistan. This dam is 335m high, formed of earth and rock fill.

The use of precast concrete and reinforced concrete in dam construction takes place in a very slow manner. Usually the field of hydraulic structure is characterized by massive structures. It is not an economical way to divide the massive structure to a set of elements to made of precast sections. This could be clearly seen from the cost price of precast concrete elements are about 1.5 – 2.0 times that fore cast in situ concrete. So as to get a reasonable and convenient way to apply precast concrete in the field of hydraulic structures, we have to make use of a constructions for these structures which give a considerable savings in the amount of concrete . If we could reach a convenient design for a hydraulic structure which is having a less amount of concrete compared to a monolithic structure then it is possible to have a useful field for applying the precast system of execution. Under such condition a considerable saving in the cost of such structures can be reached. Also it is possible to execute about 50% of the whole work in form of precast concrete section compared to the total amount of concrete used in the structure . The modern tend in the design of precast concrete structures in the field of hydraulic engineering gives the possibility to have new simple and economical constructions. This will be clear from the various structures which will be discussed later.

One of the best examples which are widely used in this field walled constructions for dams, retaining walls, and navigations locks and hydro-power plants . These structures can be made in form – monolithic and precast box type constructions in which a reduction of about 50 – 70% of the total amount of concrete volume which is normally used in a similar of monolithic structure. Soil in used in these structures so as to give the balance weight instead of concrete, which are necessary to satisfy the safety against sliding.

Precast monolithic dams of the box type construction form has been widely used in USSR and other foreign countries. Such type of dam construction has got a very good evaluation at various international conferences in China (1956), Belgrade (1958), This type of dam construction proved to have a very good field of application in dam construction for water power plants up to 30.000 KW., also it retaining walls piers and other parts of the plant.

During the last few years precast reinforced concrete was wildly used in USSR in a very fast economical and wide range of structures in the field of industry and housing construction.

Hydraulic structures are commonly made of monolithic massive construction. This is the case of dams, regulators locks and other hydraulic structures.

A main characteristic feature of these structures is to use bib volumes of concrete with a large amount of shuttering works and too much labor forces.

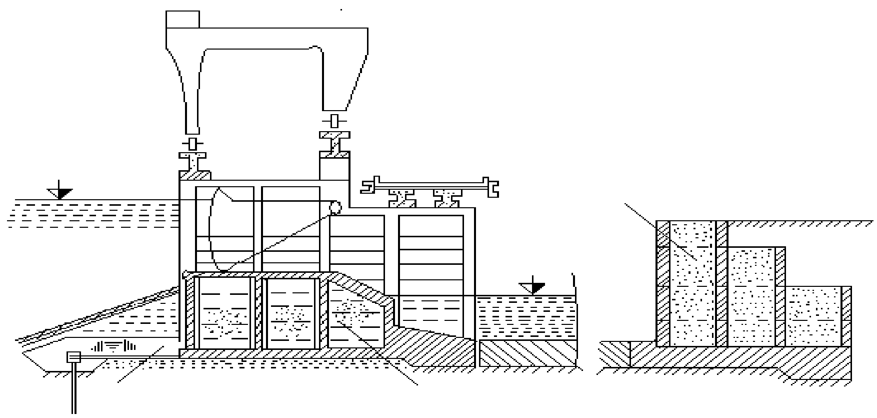
In general about 50-70% of the concrete used in required only to satisfy the equilibrium requirements against up lift or sliding conditions.
In this study it will be discussed the following points:

a. Using of Precast R.C in different construction applicable in irrigation structures.

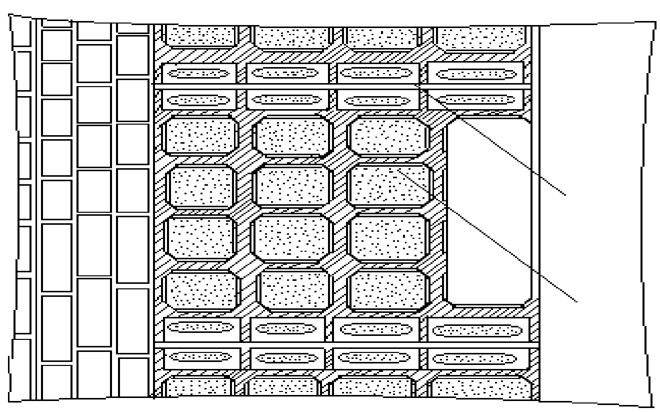
b. Dams on non rock & rock foundations using precast reinforced concrete particularly silo dams.

c. Design of silo dams under different loads in vertical and horizontal directions.

d. Benefits and Recommendation which will be gained from using such dams and means of reducing defects.



Cross-section elevation



Cross-section (1-1)

Fig (1) Cellular dam

2. ADVANTAGES/ DISADVANTAGES OF PRECASTING CONCRETE

These is no doubt that there are many advantages of pre – casting of structural reinforced concrete and pre – stressed concrete members that result in the mass production of the units in nearly all fields of architectural and engineering practice .

The classification of the products may be set down as shown below

a. Pre–cast concrete products which are made entirely in factories or central depots and conveyed to the site for erection in the structure. This group includes most of the lighter units up to say 10 tons in weight and limited in size to loads which can be conveyed by road vehicle.

b. Heavy units pre–cast on site and hoisted into position there to be bonded in to the structure by in–situ adjoining members or special joints. The limit is only that of handle ability.

c. Pre–cast structural concrete units of repetitive character forming part of a sub – divided monolithic structure like flooring units, complete flights of stairs, secondary beams, lintels, etc.

d. Pre–cast structural members used in special locations as permanent shuttering for in–situ monolithic construction.

e. Special pre–cast reinforced concrete sections made to be assembled on site there to be post–tensioned into a pre–stressed concrete structural member such as large span roofs and bridges

f. Pre stressed pre–cast structural members like floor units, secondary beams etc., hoisted into position after transport to or making on site.

The principal advantages of the use of structural precast concrete products are:-

a. **Economy in formwork and shuttering**. This is particularly important in large projects in which the cost of formwork and scaffolding for in – situ concrete might be as much as one third of the cost of the whole projects.

b. **The economy in the cost of moulds through prepetition.** A well made timber mould with plastic cement filler on interior surface and metal fittings may serve satisfactorily for over one hundred casts and a metal mould many hundreds more. .

c. The use of mass production methods owing to standardization resulting in economy in labor and increased productivity.

d. The control of all the relevant conditions in the factory enables production to precede independent of weather conditions.

e. The employment of the most appropriate method of curing ensures improved and reliable products and accelerates maturing thus increasing productivity.

f. Employment of skilled workers in production factories minimizes the need to have trained and specialized labor on site, where the work is restricted to erection and jointing.

g. Speed of construction on site is usually greatly increased especially as pre – cast units can be constructed if necessary prior to the contractor being afforded possession of the site. The time taken up by site curing is involved only in those parts of the structure which are cast as in – situ bonding members.

h. The technical control in the production factory can usually be better than that available on site with the result that the quality of the products can be controlled to uniformity and reinforcement correctly placed. This can result in economies by the use of higher stresses permitted by many of the building regulations.

i. The volumetric stability of the product can be ensured and the influence of shrinkage of the units when erected can be largely eliminated by the multiplicity of joints involved in the finished structure.

j. The facility afforded for testing of all factory made units as a matter of routine is the considerable advantage especially when the units are to be used in important structures.

The minimum periods required before shuttering may be removed are as tabulated below:-

Striking of shuttering (Time in days)

Type	Portland cement concretes			
	Ordinary		Rapid - hardening	
	Normal*	Cold [f]	Normal*	Cold [f]
Beam sides, walls and columns (unloaded)	3	8	2	8
Slabs (shores left under)	4	10	3	10
Removal of shores to slabs	10	14	5	14
Beam soffits (shores left under)	8	12	5	12
Removal of shores to beams	21	28	8	21

*Normal weather – about 60 degree.
[f] cold weather – just above freezing .

For high – alumina cement concrete the whole of the form work may be removed after the concrete has been in place for 24 hours.

Another time saving factor resulting from the use of matured pre– cast concrete members arises from the use of pre – cast flooring units which will take construction loads immediately they are set in place.

a. The provision for thermal and moisture movements in the several members of structure can be made if the units are pre – cast and the joints designed appropriately.

b. The amount of in – situ concrete, mortar or grout needed on site is greatly reduced and the work is kept cleaner and dryer.

c. Pre–cast structures provided with bolted joints can be dismantled and moved if required. Changes can be made in a structure the more easily when this form of construction is adopted.

d. For in – situ construction a surplus of material is usually unavoidably delivered to site but in pre–cast unit construction the transport is limited to that of finished units.

e. The special advantages of pre casting units in a variety of structures are brought out in the chapters which follow but here it may be emphasized that the advantages of pre–casting reinforced concrete and pre–stressed piles are that they can be constructed under controlled conditions with the reinforcement accurately placed, matured to the desired strength and driven to a specified set.

f. Compared with monolithic structures pre–cast structures offer facilities for the incorporation of special joints of use in the isolation of vibration and noise. Good sound insulation is more a question of construction than of selection of materials and the pre casting of structural concrete units facilitates the isolation necessary in the prevention of sound transmission through the structure.

The Disadvantages of Pre–cast concrete construction:-

a. Owing to the difficulty of ensuring monolithic continuity in the finished structure pre – cast concrete members may often need to be made larger or more heavily reinforced than the in – situ equivalent because of the free – ended conditions involved .

b. Expedients for restoring a high degree of and in some cases complete continuity are however described here after.

c. The need to make adequate provision for the stresses to which pre–cast units may be submitted in remolding, handling, transportation and erection. In some cases these stresses exceed those imposed on the unit in the loaded structure.

d. Care in handling and erection of the units to avoid damage and breakage. In long and heavy units the points for slinging should be determined by the designer and conveyed by an infallible means to the erector on site.

e. The difficulties often experienced in providing convenient and safe support of the unit during the formation of the in–situ jointing between pre–cast members on site.

2.1 Use of Pre–Cast Concrete in Weirs

2.1.1 Types of Weirs

i) Masonry weirs with vertical drop ;
ii) Rock – Fill weirs with sloping aprons; and
iii) Concrete weirs with sloping glacis.

2.1.2 Using of Precast Concrete in the Barrage Canal head Regulator

A canal head regulator (C.H.R) is provided at the head of the off taking canal and serves the following functions: -

i) It regulates the water level and controls the discharge of the canal.
ii) It controls the entry of silt in the canal.
iii) It prevents the river floods from entering the canal.

A typical cross section of a head regulator is shown in fig (4).

3. DESIGN OF CELLULAR DAMS

The use of massive constructions for hydro technical structures will give a clear indication to the particular features of these structures and their complicated nature of loading. Water dose not create large horizontal pressures along the water side of the structure but also it gives a considerable vertical up lift pressure which tacks place as a result of filtration flow.

It is clear that both horizontal pressures and up lift forces define the main dimensions of massive gravity dams. The weight of dam has to satisfy the safety requirements against sliding.

Also it should be clear that water does not give static pressure forces, but also it gives dynamic forces that cause vibration of the structure as a result 0f high velocities of water passing through the structure.

The big forces, which are acting an hydraulic structure, and the complicated nature of this structure causes a considerable limitations to the use of precast reinforced concrete in the field of hydraulic structure .

Up to 1955, precast reinforced concrete has been used in large hydro – power plants mainly in the form of reinforced concrete slab or shell shuttering works of massive hydraulic structures. The use of such elements causes only an amount of 2% of the whole structure to be of precast form.

After 1955 precast reinforced concrete has been wildly used in the field of irrigation structures, small and medium hydraulic structure.

One of the main types of these structures is the suspended channel flames. These structures give a perfect means for protection against seepage losses from irrigation ditches and cannels when passing sandy regions. Also these structures create a sufficient small heads in the canals which can give the necessary heads to use flexible pipe line watering system. Also these structures save quite large amounts of earth works, when these canals crosses low level areas. These structures are widely used in USSR, France, Italy and various countries

It the design of cellular dams which has no basement and filled with backfill based on the theory of transmission to backfill load to the wall and the other part to the base of subsoil that is according to Yansen's formula.

Reference GRISHEN 1980 (Hydraulics Construction).

$$Pw + y\,\gamma\,wdy = (p + dp)\,w - (t.u.dy) = 0$$

Where :-

dy : thickness of soil layer .

y : depth of soil layer .

p : pressure on soil layer downward .

p+dp : pressure on soil layer upward .

U : perimeter of cell of dam filled with layer.

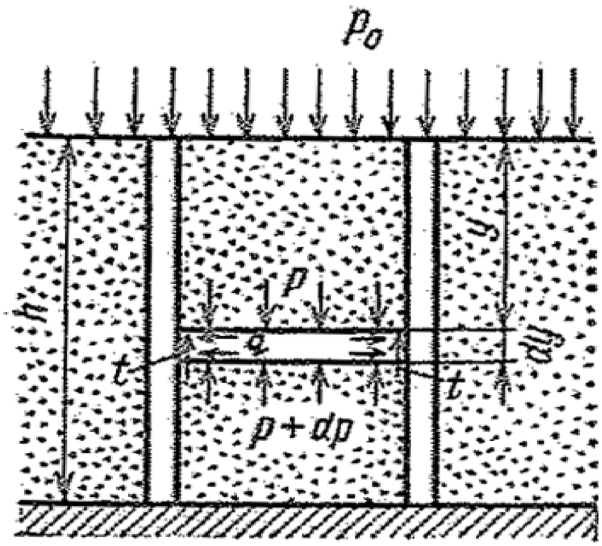


Fig (10) Stress on the element from cellular dam

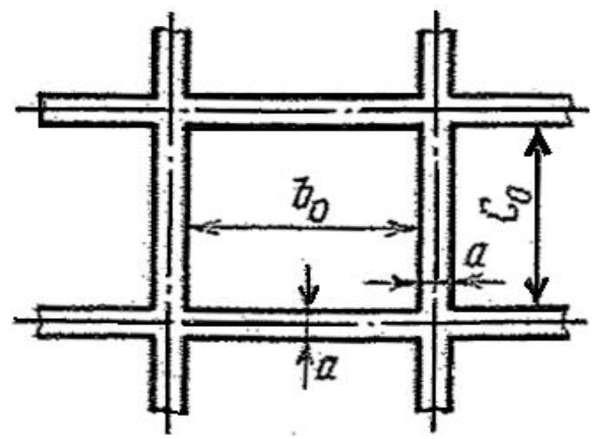


Fig (11) Block box, an element of Sectional – monolithic Structure

Friction force acting on perimeter of the soil layer.

N.B Friction force acting on perimeter of the soil layer.

N.B. Friction force is directly proportional to lateral soil pressure

P tan2 (45 – Ø/2) where the friction force equal t = fp (45 – Ø/2) = kp

Where

Ø	Angle of internal friction of soil .
f	Coefficient of friction of soil with wall .
γ wdy	Actual weight of soil layer .
w	Equal b_o c_o

Eqn of equilibrium can be written as:-

$$Pw + \gamma wdy – (p+dp)w – tudy = 0$$

The above equation led to :-

$$dy = dp (\gamma -tu/w) = dp/(\gamma- kup/w)$$

By integration for h (from o to h) and P (from Poe – kuh/w

$$P = g w/ku (1 – e kuh/w) + Poe-kuh/w$$

Where (e) is natural logarithmic = 2.72

Pressure force acting on basement area is Pf = Pw

Taking the live load into consideration then the force transmitted to the cell wall are Pw equal Pw = P- Pf = (P-gsh – p)w

In case of acting horizontal force Q and two perpendicular force Pw and Pf in wall and base of cell then the shearing force can be obtained from the formula :-

$$Ks=(f1+Pf + f2 (pw + S) / Q$$

Where

f_1 Coefficient of friction with backfill.
f_2 Coefficient of friction of wall and backfill.
S Weight of walls with live load.

Cellular dam can be constructed of elements made of fabricated precast elements i.e.

We consider a dam with concrete wall thickness 50 cm and the height of dams from 15m-max height-and 9m in (min.height).

The dimensions of the cellular dam are 3×3 m. The cellular dam is filled with sand.

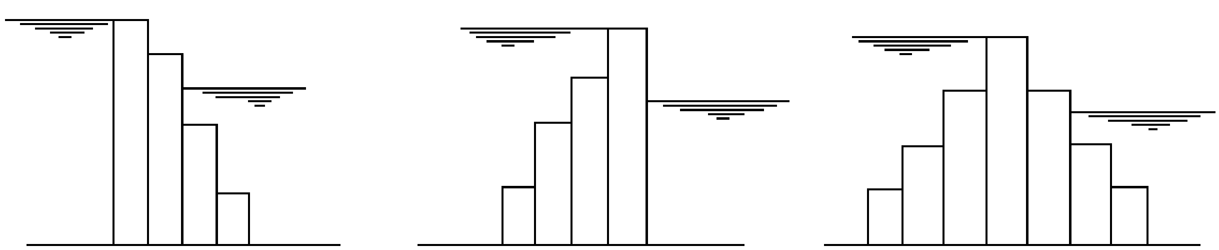
The dam is constructed with a concrete base. It is required to study the change of dimension of the base to reach the economy and safe dimension of the dam. Different soil condition will be studied. Depth of soil layers so as to reach the affected depth under should be taken into consideration.

Also a study for the method of construction of the dam and the required time for each stage of dam construction that dose not affect any cracking or unsafe settlement on soil under dam from the next studies we notice that the factors that we are taking into consideration are very useful in designing cellular dams which are used as one type of dams and as in other purpose as abutment in bridges that are constructed in reverse.

This Study discusses the model of cellular dam as illustrated.

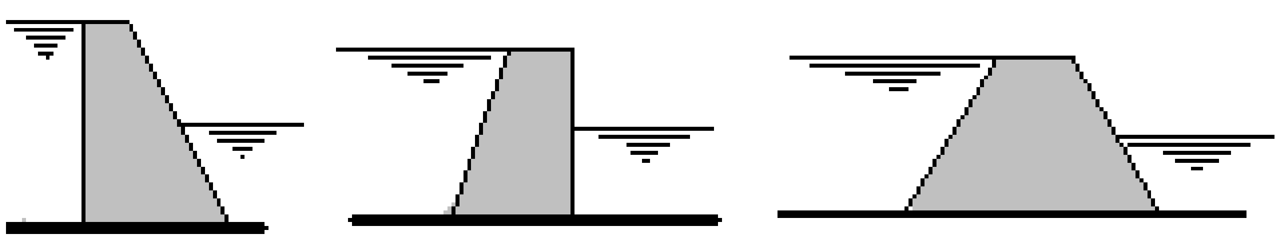
4. PROFILES OF CELLULAR DAM

It is recommended to approach the shape of dam to one of gravity dam to calculate easily the forces and stresses acting fig, (7).We can see by modern analysis method life finite element we can study the profile of cellular dam and its forces and stresses acting fig, (7).



(a) (b) (c)

Profiles of dam for $\alpha_1 = 0.5$ ‘ and $k_2 = 1.3$



(a) (b) (c)

Fig (12) Different Shapes of cellular dam

5. BENEFITS AND RECONDITIONS WHICH WILL BE GAINED FROM USING SUCH DAMS, AND MEANS OF REDUCING DEFECTS

5.1 Benefits which will be Gains from using such Dams and Means of Reducing Defects

If we need to talk about Silo dams we will talk about the way of reducing 40-60% of reinforced concrete because this way is very simple for constructing dams and the construction may be put between the mountains in Hurghada and Sharm el Shikh to use the rain water for irrigating the plants.

5.2 Recommendations

a. We can use this type of dams for example in Hurghada and sina to protect this area on the rain times.

b. The construction depends on the Row material of the Site.

c. Moving the Precast concrete from the factory to the site by easily and we don't need any provisional labors to construct these types of dams.

d. According to the head of the water level and the stress of the soil, we can determine the cross-section area and the shape of the silo dam by a very simple way.

e. It's very easy to estimate the cross-section of the dam to achieve the stability between the weight of the dam and the pressure of upstream water.

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