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INTERNATIONAL CONFERENCE ON DEVELOPMENT OF
LOW COST AND ENERGY SAVING
CONSTRUCTION MATERIALS AND APPLICATION

ROLLCRETE - AN ECONOMICAL ALTERNATIVE FOR NEW PROJECTS

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SUMMARY

The present paper has the purpose of showing the importance of the tendency in using new construction techniques in mass concrete structures.

This paper also refers to the use of Roller Compacted Concrete-Rollcrete, as an alternative, to reduce overall costs of hydraulic or massive structures.

The State-of-Art of the above mentioned technique, used in Brazil and abroad, is also presented herein.

Overall information in respect to the various properties of this type of concrete is another topic of the present work.

Finally, an overall design criteria is suggested when using the above mentioned technique, with the purpose of achieving a greater reduction of construction costs for future projects.

1 - INTRODUCTION

As overall data regarding the physical characteristics of Brazilian River Basins are becoming available, and as viability studies regarding the construction of new hydroelectric power plants are being developed, a large and progressive range of knowledge in respect to Brazil's Hydraulic Potenciality, is being acquired.

The above mentioned data, regarding Brazil's hydraulic potenciality, has pointed out a total available capacity of 106.570 MW year [4], with reference to 1980.

In terms of installed capacity, this firm power corresponds to a total value of 213.000 MW, with a load factor of 50%.

The above mentioned firm power is subdivided according to its availability in the following regions [4].

REGION	FIRM POWER(MW YEAR)	%
North-Middle East	49.369	46
Northeast	7.303	7
Southeast-Middle West	25.484	24
South	24.414	23
TOTAL	106.570	100

The physical characteristics of the aforementioned hydraulic potenciality, in terms of installed capacity, gross head and firm power, are estimated in [4]:

GROSS HEAD (m)		INSTALLED CAPACITY - MW (FORECAST)			
		UP TO 40	41 to 400	ABOVE 400	TOTAL
Up to 10	Number of Power Plants	240	6	-	246
From 11 to 30	"	1601	105	17	1723
From 31 t0 50	"	652	99	16	767
From 51 to 100	"	424	145	41	610
Above 100	"	97	54	16	167
TOTAL	"	3014	409	90	3513
	MW - YEAR	12951	24807	68812	106570
	% MW - YEAR / TOTAL MW	12	23	65	100

It is also verified that the greater portion (65%) of hydraulic potencial is concentrated in 90 projects with a hydraulic potencial above 400 MW, and that the number of small projects with hydraulic potencial below 400 MW exceeds 3000.

It is also important to point out that, according to previous experiences, the forecast of a total of 106.570 MW year, tends to increase in future, due to more precise information.

Under the point of view of energy consumption, it is expected [4] that from 1984 onwards, there will be an increase of 10,8% up to 1990, due to the following factors:

↳ MAIO 84 – 10%
ÚLTIMOS 12 MESES 9,3%

- recovery of the national economy;

- greater consumption of electrical energy in substitution to by - products of oil.

The examination of the energy balance after 1985, indicates a necessity of a complementary construction programme involving approximately 24.000 MW.

One should also consider that the construction of power plants in the North region requires additional attention due to the climate, logistic and supplies of basic materials and small amount of human labour, as well as existing substructure.

Taking into consideration the forecast of future projects which can reach a number of 500 new power plants reaching 90% of the available capacity (reference 1980), one should analyse the overall costs of these undertakings when using the design and construction techniques used until now.

One should also keep in mind that a great number of these undertakings shall be carried out in the North Region (Amazon), what may mean even more costly designs, considering the use of earthfill and rockfill dams, with clay core.

The purpose of the present paper is to discuss a new technique which is being very used in Japan and U.S.A., which is very economical and time saving when dealing with massive structures, as in the case of hydroelectric power plants.

The above mentioned technique is known as "Roller Compacted Concrete" - RCC - ROLLCRETE.

2 - CONCEPT

This technique uses a mixture without workability with a sandy aspect, which can be compacted by equipment normally used in the construction of earthfill and rockfill structures, permitting a continuous placing, as well as allowing an economical and time saving solution in the construction of gravity type dams, or any other massive structure.

3 - STAGE OF DEVELOPMENT AND USE

The Rollcrete technology is relatively recent.

The first publications and discussions regarding this subject, occured during the Asilomar Conference (California - USA) in March 1970.

However, the difussion and application of this technology has been very intense, proving to be very economical in several civil engineering works where it was used.

The development of Rollcrete technology practically started in 1970, by renowned entities such as T.V.A. and the Corps of Engineers.

This process has been used in various civil works, such as:

- Cochiti - New Mexico
- Lost Creek - Oregon
- Moose Creek - Alasca
- Boneville - Washington
- Applegate - Oregon

UPPER STILL WATE - EUA.

- Revelstoke - B.C. Canada
- Shimajigawa - Japan
- Tarbela - Pakistan
- Willow Creek - Oregon
- PIRIKA
- OKAWA - TAMAGAWA } JAPÃO

In particular, the Willow Creek Dam, was designed and constructed by the Corps of Engineers, intirely in Rollcrete, proving to be more economical than the rockfill alternative.

In Brazil, the rollcrete technology was applied in Itaipu, for the construction of the warehouse's floor, in 1976. It was also used in São Simão Hydroelectric Power Plant in 1977, to plug a diversion structure.

433 In 1978 there was an application of 26.000 m^3 of Rollcrete in Itaipu for the access to the river diversion foundation structure.

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In 1982, the guard walls of Tucuruí Navigation Lock were constructed in rollcrete, the design being developed by THEMAG.

The economical, technical, as well as time saving advantages resulting from the use of rollcrete, duly presented in the present paper, are the main factors which lead the main entities, responsible for the construction of mass structures, to invest in the research of this new technology.

4 - TECHNICAL CHARACTERISTICS

4.1 PREAMBLE

Rollcrete differs from conventional mass concrete basically in its fresh mixture form and compaction process.

Whilst conventional mass concrete presents a moisture ratio which permits the use of slump test, widely used to measure the consistency of concrete, and can be moulded in various forms with the aid of immersion vibrators, rollcrete presents a dry, sandy aspect without any moisture, being compacted by external vibration, usually carried out by rollers.

This diferrence in aspect between the two types of concrete, is caused by the reduction of water and cement in the case of rollcrete (for a same required strength), and by the increase of new proportions of fine and coarse aggregates.

The alterations regarding the compaction process and mixture proportioning, cause a few differences after hardening, in respect to aggregate gradation, fresh mixture control and technological properties, which will be duly presented in item 4.2.

4.2 PROPERTIES

Since 1970, many entities of several countries have been trying to developed test methods and quality control techniques, for rollcrete.

The first difficulties arose during the above mentioned studies, mainly because of the dry characteristic of the mixture.

Regarding hardened concrete the availability of data in respect to deformation capacity, is still very small due to the difficulties in obtaining beams for flexural tests.

- Fresh Mixture Proportioning

  Whilst in the conventional mass concrete, the ideal percentages of sand and cement are basically determined by the slump test, in the case of rollcrete, the process which has been presenting the best results, is the determination of maximum density of mixture, after compaction as function of percentages of these materials.

- Production Control

Besides the normal control procedures of materials, the most efficient control of moisture in the mixture, is by oven drying.

- Compaction Control During Concrete Placing

Has ussually been carried out by topographical survey in respect to the width of the various layers of rollcrete, as well as by the number of times the equipment compacts these layers and by the density of each compacted layer, with the aid of nuclear densimeters.

- Specific Weight

Rollcrete normally presents a density of 2 to 3% higher than conventional mass concrete, due to its greater amount of aggregates.

- Compressive Strength

For equivalent water/cement ratios, the strengths which were achieved in rollcrete are 30% higher than in conventional mass concrete (for ages over 90 days), due to the greater degree of compaction caused by the use of compacting rollers, as well as by the lower water ratio in the mixture.

- Tensile Stength

Rollcrete presents a tensile strength, which obeys approximately the same variation law as in conventional mass concrete (10 to 15% of axial compressive strength).

- Shear Strength

Also presents the same proportions, in relation to simple axial compressive strengths, as found in conventional mass concrete.

- Modulus of Elasticity and Creep

Low age rollcrete has been presenting lower values of modulus of elasticity, and higher creep when compared to conventional mass concrete.

For higher ages, these properties for both types of concrete are similar.

This fact is due to the lower paste contents and higher porosity presented by rollcrete. In more advanced ages, these properties are governed by the coarse aggregate.

- Volume Change

Due to a lower paste content, rollcrete presents a smaller change in volume when compared to conventional mass concrete.

- Strain Capacity

The present availability of data regarding strain capacity of rollcrete doesn't permit a conclusion in respect to this property.

However, one may assume that the strain capacity in rollcrete is at least similar to conventional mass concrete.

- Thermal Properties

The differences between the two types of concrete in respect to the Specific Heat, Thermal Diffusivity, Thermal

Conductivity and Coefficient of Thermal Expansion is very small, mainly due to the amount of aggregates used in the production of rollcrete.

- Temperature Rise

The temperature rise in rollcrete is smaller than in conventional mass concrete, due to the lower cement content.

- Absorption

The absorption factor in rollcrete is greater than in mass concrete due to its higher porosity.

- Permeability

Whilst conventional mass concrete presents permeability factor around 10^{-11} cm/s, rollcrete presents, in its present stage of development, permeability ratios around 10^{-5} to 10^{-9} cm/s, for cement consumptions which attend elastic-mechanical design requirements.

The greater porosity of rollcrete is also the cause for this difference.

According to the aforementioned comparisons, regarding the strength, elastic and thermal properties, one can notice that rollcrete presents several advantages over conventional mass concrete, when applied in large structures.

In respect to the deficiency in respect to permeability and absorption properties, this can be overcomed by the use of a conventional mass concrete "casing" (in hydraulic structures) and by means of drains, in the contact areas between rollcrete and conventional mass concrete.

5 - USES OF ROLLCRETE

By analysing the properties of Rollcrete, one can verify that it can be used in gravity type structures with significant advantages over conventional mass concrete.

The gravity type dams, built with conventional mass concrete, are being normally designed having a downstream face slope wich varies from 0.7H:1.0V to 0,8H:1.0V.

The design of a gravity type structure using Rollcrete will not suffer any alterations regarding basic design criteria.

Nevertheless it is worthwhile mentioning that a few modifications can be studied for the optimization of projects using this type of material.

As such, the design of Upper Still Water Dam (UTAH-Bureau of Reclamation), with a height of 65m, is foreseeing a section with a downstream slope face of 0.6H:1.0V. This may permit a reduction in volume around 20% to 25% when compared to sections with 0.8H:1.0V slopes, and around 12% to 15% when compared to 0.7H:1.0V slopes.

In the other hand, the Corps of Engineers has been studing construction conditions using downstream slopes of 0.8H:1.0V however without the use of formworks, making a natural slope with compacted material as carried out on the Willow Creek Dam.

Due to the fact that the mechanical properties of Rollcrete are better than in the conventional mass concrete, with equivalent consuption, the sliding and overturning conditions are improved when using rollcrete.

Furthermore, considering the advantages of the thermal and elastic properties of rollcrete, the spacings between contraction joints can be optimized and reduced or even removed, depending on the conditions as in the case of Willow Creek Dam.

Still, considering the advantages of the thermal and elastic properties of rollcrete, over conventional mass concrete, the plan of construction joints between layers can be altered, based on thermal stresses studies thus permitting a continuous placing.

This can be evaluated by means of studies, as the ones carried out for Willow Creek.

The combination of the aforementioned technical advantages, can allow substancial alterations in the overall construction schedule.

6 - EVENTUAL ADVANTAGES OF THE USE OF ROLLCRETE

Based in the aspects which were presented in former chapters, one can find various advantages in the use of Rollcrete, which amongst others comprise:

- Reduction of human labour;

- Reduction of construction time, consequently reducing costs, without the necessity of an increase of equipment resources;

- Reduction in quantity of the types of equipments for the transport and placing of concrete;

- Simplification of the aggregate and concrete production systems, as well as of the cooling system, with consequent reduction of costs;

- Reduction in quantity of the basic materials for concrete production;

- Reduction in quantity of types of formworks;

- Reduction of substructure (townships, schools, dinning rooms, hospitals, etc...)

- Anticipated generation or regulation providing additional advantages.

As an example of these advantages, the values obtained during the construction of Willow Creek [4] will be put forward:

"The inical cost estimate for Willow Creek Dam, was around US$ 32.000.000 for a rockfill type structure. Later, this value was altered to US$ 25.000.000, based an a rather less conventional design. The construction period was scheduled to be in 3 years.

The design, considering rollcrete was then, carried out, and the construction schedule decreased to 1-2 years.

During the development of this design, and based upon studies and tests results the estimated cost was reduced. The estimated cost used for bidding was US$ 14.000.000, saving US$ 11.000.000 in relation to the lowest price of the Rockfill alternative".

Furthermore, the dam started its operation in 1 year and the contract completed in 1.5 years.

Therefore, there was a reduction of 44% in the final cost, when comparing the Rollcrete against the Rockfill solutions.

The total volume of Rollcrete used in Willow Creek was approximately 330.000 m^3.

7 - COMMENTS.

The main purpose of the present work is to promote a debate regarding the possibility of the use of this new technique, in order to achieve a substantial economy in the construction of future mass concrete structures.

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