

**COMPLEX TECHNOLOGY FOR THE PREPARATION
AND THERMAL TREATMENT OF HIGH PERFORMANCE CONCRETE**

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Abstract

High performance concretes possess a series of particularities respective to the middle class ones. The high dosage of cement and the quite reduced ratio water/cement require that the procedure of intensifying the cement hydration be applied in a slightly reduced manner. Apart from the known elements intervening in the structural formation of the cement stone hardened at supernormal temperatures, we also take into consideration the necessity of an uniform and penetrating hydration of the cement grains, the need to separate and disperse them homogeneously in the mixture, to improve the contact between the grains and the water and to reduce the screening effect.

Key words: deformations, control, concrete

1. INTRODUCTION

The causes leading to the deterioration of construction during the service period are multiple. Among these, excessive deformations can produce spectacular and serious degradations.

The control of deformability of the reinforced concrete elements has become a serious problem because of the introduction of breaking tests and limit states calculations, as well as the amelioration of concrete technology and the use of steel reinforcements of high resistance. Consequently, the elements have become slimmer and therefore more deformable.

The increase of steel quality to the detriment of the quantity of reinforcement or the geometrical sizes of the concrete section has a certain unfavourable influence on the elements' deformability.

Many difficulties appear when trying to prevent the deterioration produced by excessive deformation and to consider the multitude of causes producing deformation in the reinforced concrete elements and their synergetic action, as well as the variety of deformations observed (measured) reported to the estimated ones or established in laboratories.

The causes of deformations occurring in the reinforced concrete elements are: external loads or stresses, rheological phenomena of the concrete (contraction, bulging and slow flow), the temperature variation of the environment and the settlement of bearings.

The complete analysis of the constructions behaviour during service does not allow a separation between the limit states of deformations and those of cracking, since the second one has a great influence on the first one.

Limiting the process of cracking guarantees the rigidity the constructions need and satisfy the exigencies related to their deformability.

The calculation procedures for the limit deformation state stipulated by design norms mainly consist in

evaluating the deflections in the cracked area and limiting them at acceptable values that guarantee normal working of the elements, of the component parts of the resistance structures or the structures as wholes.

There are situations when deformations can affect the safety of the entire structure. Thus, ductility represents the capacity of developing important plastic deformations before breaking and it constitutes an essential condition both for the retransmission of stresses into the undetermined static systems calculated in the plastic field and for the satisfactory behaviour of the structures situated in seismic areas.

Furthermore, the instability phenomena require a good knowledge of the deformability characteristics of the structure and the time effect on the structures' behaviour. This type of actions is part of the ultimate limit states category.

Excessive deformations appearing during the service stage of the reinforced concrete constructions cause inconveniences related to the aspect and functionality (working) of the elements or the structure they are part of and they also damage other structural or non – structural elements connected with them.

The aspect of the elements with severe deformations can worry the beneficiaries or the inhabitants of the construction. Hence, excessive deflections are to be avoided in the visible elements.

Generally, the human eye is not very sensitive to perceive deflections unless there is the possibility of comparison with the line of the undistorted bearing elements or the eye of the observer is at the same level as the one of the deformed element.

The general idea is that a deflection higher than $1/250$ of the element's opening is to be avoided for reasons of aesthetics.

There are numerous forms of manifestation of damages on functionality or the loss of structure's capacity to satisfy the function it has been constructed for because of the apparition of excessive deformations appeared. These are:

- Water collection in the areas with excessive deformations of the roof – floor
- Difficulties in a proper functioning of doors and windows
- Impediments for good functioning of equipment
- Vibrations appearing in elements with insufficient rigidity in bending during service stage.

The deterioration of non – structural elements represents the most common consequence of excessive deflections of strength elements involved and consist in cracks on partition walls and closing elements or several difficulties in the proper functioning of doors and windows.

The deformations on a resistance element represent forced deformations for other resistance elements it is connected or it bears on. On the contrary, a shift of the bearings constitutes a forced deformation in hyper-static systems.

To avoid unwanted consequences that might appear in these situations, specialists has stated that limiting the deflections of the concrete flooring to $1/200$ of the opening makes possible a satisfying behaviour of the carrying – masonry walls it stands on.

2. THE EFFECTS OF THE DESIGN AND EXECUTION ERRORS ON THE REINFORCED CONCRETE STRUCTURES

As it happens in several other fields, the activity in constructions goes along with a number of miscalculations. These errors reduce the class of the building and can have severe and varied outcomes:

- Make the user/beneficiary to be suspicious
- Create abnormal conditions for the use of the construction
- Reduce the durability of the elements or the structure as a whole
- Reduce the safety rate of the construction
- Increase the volume of works and investments needed.

Glaring errors or mistakes are important ones occurring rather rarely and owed to human negligence and sometimes to his lack of experience and training as shown in figure 1.

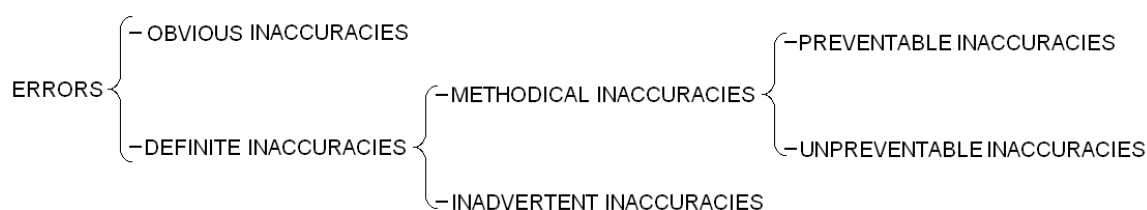


Figure 1. Classification of errors

Conducting a serious control should eliminate errors or at least reduce them to a minimum probability. Specific errors are quite small, with similar values and small differences between them. Depending on their character there are two subgroups: systematic errors and accidental errors.

Systematic errors are produced by permanent causes which act under more or less known laws. They can be caused by errors of calibration of measuring devices, execution errors of the equipments used, the equipments wear out, etc.

Usually, they have the same sign and very small variations. Since their causes are permanent they can be discovered and eliminated with judicious and proper measures, as is the case with avoidable systematic errors. Still, there are cases when the errors cannot be avoided.

Accidental errors are inherent to the production process and they have small values and variable sign. A thorough preparation and organisation of the production process will reduce their value but not eliminate them.

Their causes are multiple: variation in the quality and characteristics of materials, the worker's mood and physical tiredness, the influence of the environment etc.

3. METHODS AND MEANS

Apart from the known elements intervening in the structural formation of the cement stone hardened at supernormal temperatures, we also take into consideration the necessity of an uniform and penetrating

hydration of the cement grains, the need to separate and disperse them homogeneously in the mixture, to improve the contact between the grains and the water and to reduce the screening effect.

Therefore, the experiment consisted in producing concrete by mixing the aggregate with the water cement. The water cement has been previously obtained by a process of forced mixing in an 800 rpm mixer. The forced mixing was conducted both at a normal temperature and at a temperature of 65 ... 70 °C.

The forced mixing of the cement milk at normal temperature or even subnormal one has the advantage that, from a technological point of view, it can provide the binder with favourable conditions for a partial and preliminary hydration, only when the hardening process has not yet begun.

The first formations on the surface of the grain are then cleared away by forced mixing in two or three rounds and passed away in the area of the free liquid.

Thus, there are fulfilled all the premises for the cement grains to fully combine with water, regardless their size or the temperature at which the concrete is going to harden after it has been poured.

When the aggregates and the cement milk have been blended in the concrete mixer, the concrete's waiting time in moulds at normal temperatures can be seriously reduced. After the time has expired, it follows either an artificial thermal cycle respecting the known procedures or a natural thermal cycle obtained by green house effect.

The procedure, as it is easily understood, ensures optimum use of the cement, it eliminates the necessity of supplementing the dose of cement characteristic to fast-hardening concrete, but provides an insufficient increase of the strengths in initial stage.

To obtain a more intense acceleration of the hardening process, respectively a significant increase of the initial strengths, it is recommended that the preparation of cement milk using the procedure described above is performed at high temperatures, at least 50°C; in the concrete mixer, the cement milk will be blended with the other aggregates which are previously heated.

Among several disadvantages, this technology has one essential advantage: it eliminates the destructive effect of differential expansion of the concrete's components, with all the consequences already presented.

The concrete is poured into preheated formworks at a temperature similar to the one established for the isothermal period, after which it is vibratory compacted using high frequency vibrators.

Thus, the negative effect of the first formations of tri calcium hydro – aluminates on the compaction degree of the material is felt more reduced because they are dissipated by the vibration.

Experimental researches showed that the loss of water as a result of the processes of preheating, mixing, pouring and vibration amounts to 38...50 litres per cubic metre of concrete; this aspect is significant for the choice of concrete's composition. Also, there are two aspects that may concern the producer.

The first one refers to the increase of energy consumption during the first stage of the elements' production by using specific technologies. The second aspect refers to the fact that the suggested elements complicate the classic flow of concrete dosage and pouring.

As already shown, within an usual thermal treatment of the prefabricated concrete elements the biggest energy consumer is the period when temperature is increased.

This is compensated by the total energy consumption intended for preheating the cement milk and the aggregates.

Beside this, the isothermal treatment of the concrete can be shortened to almost half in the conditions in which the binding capacity of the binder is superiorly used; the initial strengths are higher and the structural flaws are significantly reduced.

The tests conducted by researches have proved this aspect and the strengths obtained at the end of the thermal treatment cycle had really surprising values.

It is true that the classic flow of concrete preparation suffers small perturbations, but using several additional working procedures which are thoroughly organised, the suggested technology could be implemented. 24 hours after the concrete has been poured into the prefabricated elements, these can be manipulated and delivered to the consumer. Once the concrete compositions has been established, the total quantity of cement that will be part of the composition is divided as follows: 60 ... 65 % of the pre – established dose together with 85 ... 90 % of the quantity of mixing water are put into the mixer, the final result being cement milk with a reduced viscosity.

Depending on the type of cement used (fast-hardening or regular), the cement milk remains in the agitator for a period of 60 ... 90 minutes, while it is forcedly mixed in three rounds of 45 ... 60 seconds each.

This procedure is conducted at normal temperature with two results: the homogeneous dispersion of the granules into the mixture and the remove from the granules' surface of the first hydration films and their further transition in the area of the free liquid.

Thus, the hydration process is more profound and the use of the binder is optimum, with direct effects on the initial and final strengths of the material. The rest of the cement is mixed with the quantity of water remained and it is stored near the concrete mixer. The process of hydration of the mixture will be slower, but more profound as the temperature is lower.

In order to have a best treatment of the concrete at high temperature, this mixture should be kept at a temperature of + 4 °C for the next 2 ... 3 hours.

When the time of the two procedures has expired, the cement milk and the cement mixture are poured into the concrete mixer over the aggregates and are normally mixed. The concrete prepared as described above is then heated in a separate bin, and then it is transported on the construction site where it will be poured into formworks which were previously heated at 70 °C.

Afterwards, the concrete will be compacted while it is still warm. This procedure consisting of transporting, manipulation and casting of the concrete while it is in a highly active state is suitable for the use in prefabricated plants where the above operations can be conducted in a minimum period of time with no repercussion over the compaction and composition of the concrete.

In the case of fast – hardening concretes, the three operations should be performed while the concrete is cold. The technology is to some extent simpler because the heating procedure in the bin and the two operations of transport are no longer required.

In this case, the heating will be performed directly in the casing with an increase of temperature as fast as possible and depending on the thermal equipment of the plant.

There is to be mentioned the fact that the choice of preparation and thermal treatment is determined by many aspects, of which the most important are:

- The initial and final strengths expected from the concrete
- The type of cement used in the process
- The energy possibilities of the producer

- The economic aspects determined by the price limit the beneficiary has agreed on
- The agreed time length for the delivery of elements.

Any additional equipment the producer agrees to purchase in order to conduct these technologies.

CONCLUSIONS

In the light of the above, the following conclusions can be drawn:

The high – performance concretes are necessary for the realisation of elements and structures with initial strengths, as well as for the construction of tall buildings; this type of concrete is obtained by using high dose of superior quality cement and special technologies for further working and treatment.

Especially in the case of prefabricated elements, it is compulsory to accelerate the hardening process by thermal treatment in order to reduce the time of the production cycles and to make the production units efficient.

Beside the obvious advantages of reducing the time of the hardening process and obtaining the strengths needed for removing the concrete forms, the transport, the transfer of the pre-compression force etc, thermal treatments produce major destructive changes in the structure of the concrete.

Among these changes, most important ones come from the differential expansion of the concrete components and of different layers within the same element, from the screening effect of the cement granules and the premature loss of a rather significant quantity of the free water.

To compensate the losses of strength produced by these effects, the current technologies recommend the increases of cement dose and the introduction of a waiting time at normal temperature when the concrete is in the formworks. Both measures have a negative economic impact while the technical effects are not spectacular. In order to reduce some of the structural flaws and to intensify the hydration process, it has been suggested the preparation of concrete using components which are preheated at the same temperature as the one required for the thermal treatment.

The result was a considerable shortening of the thermal cycle and a relative improvement of the concrete's quality. Still, the preheating process does not properly solve the issue of an optimum use of the chemical energy the concrete possesses; therefore, most part of the binder introduced in the mixture is not used.

Using the procedures of waiting and then forced mixing in powerful mixers, the preliminary preparation of the cement milk makes total use of the binder, especially in the case of fine grained cement.

The combination of the two procedures may result in important increases of the initial and final strengths, with minimum losses at 28 days in relation to the strength index obtained in normal conditions of concrete hardening.

Furthermore, the increase of the cement dose is no longer necessary. The thermal cycle is significantly reduced since the two operations take place out of the proper thermal cycle.

This complex procedure is indicated for relatively small quantities of concrete or in the case of moderate – hardening cements. The preparation, transport and working operations have to be completed within a limited frame of time, because a premature rigidity of the concrete may compromise the quality of the elements.

In the case of fine grained superior cements it is recommended that the mixing process of the cement milk is conducted at a normal temperature, and only after the concrete has been prepared and poured the temperature may be increased to whatever high value, followed by an isothermal treatment and cooling.

The technical and economical advantages of the suggested technology are obvious:

- Significant reduction of the structural flaws
- High initial and final strengths
- Economy of the cement quantity
- Reduction of the production cycles
- Reduction of the energy consumption per cubic metre of prefabricated element

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