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COMPARATIVE DESIGN ASPECTS OF REINFORCED CONCRETE LIQUID RETAINING STRUCTURES

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Abstract. The Reinforced concrete liquid retaining structures must be designed so that the facility to be safe from leakage. One of the determining factors for the design of reinforced concrete liquid retaining structures is design with restriction of cracks. According to EN 1992-3 are defined four tightness classes in order to show degree of protection against leakage in design of reinforced concrete liquid retaining structures. In general, design of reinforced concrete liquid retaining structures can be done in two main cases: design without cracks and design with induced cracks which are controlled one. In this paper is shown the case where in design are foreseen to apply the concept of controlled cracks by application of joint tube for induction of cracks which takes rheological effects of concrete. The rheological effects of concrete can cause cracks which on one side are very difficult to predict where they will appear, while on the other side the appearance of these cracks greatly affects the degradation of the structure. Joint tube for induction of cracks is applied to eliminate these effects. The practical application of this concept was done during the construction of the facilities of a drinking water treatment plant in our country and it was concluded that exactly the purpose for which they were applied was achieved. This concept is foreseen also by EN 1992-3. The benefits of applying this concept are numerous and the most important is the safety that is achieved against leakage.

Keywords: Reinforced concrete liquid retaining structures; Controlled cracks, Induced contraction joint; Limitation of cracks; Protection from leakage; Tightness classes.

Introduction

Proper design of reinforced concrete liquid retaining structures by which design is achieved to ensure the structure from leakage is definitely a challenge in construction engineering. In this case, the mechanical aspects of the actions on structures and the quality aspects of the materials to be used must be taken into account in the design. The application of innovative methods of design and construction of these structures has been found to be more efficient than standard classical methods. Among the most efficient methods is controlled crack design which is achieved through the use of induced cracks in certain concrete sections of the structure's elements.

Design principles of reinforced concrete liquid retaining structures

In general, the design of reinforced concrete liquid retaining structures can be done in two main concepts:

1. Design of structures with cracks limitation or without cracks, whereby the purpose of cracking restriction is achieved by the acquisition of the dimensions of the structure elements on the one side and the application of certain forms and amounts of reinforcement on the other, as recommended with design codes, in this case with EN 1992, and
2. With the application of induced contraction joints where the cross-section of the concrete element is deliberately reduced in order to cause cracking at the desired position of the structural element of the structure.

This paper aims to present the advantages of applying the second case, namely causing cracks that can be controlled.
The design case with controlled crack design is included also in EN 1992-3 where Annex N and paragraph 9.6.6 provide recommendations with measures to be taken into account when applying this concept.
Having in consideration of the need for leak protection and in order to apply this concept when applying controlled crack, different manufacturers have issued different products with the application of which this goal can be achieved.

Practical application of the design with controlled cracks

This paper will present the practical application of design with controlled cracks in one project of water retaining facilities implemented in Kosovo. The water retaining facilities where this concept was used were facilities of a drinking water treatment plant and therefore we had to adopt a solution that ensured that there was no leakage from the walls of the facilities (the leakage had to be prevented either for the outflow of water from the facility or even for the outflow of water into the facility from outside which in this case was the soil behind the walls).
After analyzing the possible solutions, we have come to the conclusion that the most efficient solution in our case is design with controlled cracks. For this purpose a joint tube for induction of cracks is provided. This tube is placed in the middle of the wall while in the two sides of the wall before concrete pouring are mounted triangular shaped wooden bars to leave a space which after removal of the formworks are filled with waterproof mortar, this waterproof mortar has flexible mechanical properties.
In the case of the flucctuation of creep and shrinkage of concrete and also flucctuation of loads in structural elements (walls) than joint tube for induction of cracks and insulation grout in gaps has enought flexibility capacity to accept these deformations without suffering damage that may cause leakage, so even after all kinds of potential impacts these imposed controlled cracks remain functional.
The joint tube for induction of cracks consists of thermoplastic PVC material which is weldable to other water-stop bars or tapes thus in combination forming a closed loop waterproofing. The tube has six ribs which have some teeth-shaped parts, so the geometric shape of the tube and its ribs enables a good bond with the surrounding concrete. As shown in detail, the pipe has two ribs that have no teeth, and these two ribs should be positioned normal to the outer surfaces of the wall. The material of which the pipe is made has a slight increase in volume from the chemical reaction when it comes into contact with the wet concrete providing even more bonding between the pipe and the concrete. These tubes are usually fitted with a U-PVC material pipe inside to hold the pipe in proper position.

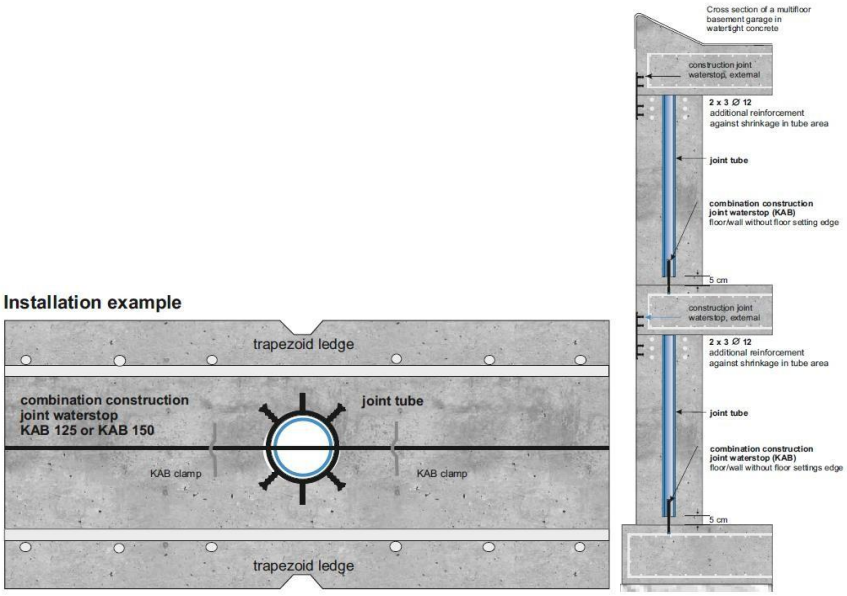

Figure 1: Detail for the placement of the tube in concrete wall

Figure 2: Images from practical application of joint tubes for induction of cracks in concrete wall

The principle of operation of this concept of controlled crack is based on obtaining the rheological effects (shrinkage and creep) of concrete from the joint tube for induction of cracks which is very well bonded to the concrete and thanks to the very good properties of the pipe it accepts all impacts without transmitting them to the concrete.

In the above mentioned project the geometric shapes of the facilities have been rectangular. In rectangular shaped facilities it is easier to determine the proper position for pipe placement.

The proper position for tube placement is assumed where the stiffness of the structural element (in this case wall) or the stiffness of the structure is the smallest which of course coincides with the position where the impacts from the concrete shrinkage are maximal as well, and also static impacts are maximal.

In fact, the concept of applying the joint tube for induction of cracks is based on the cracking caused by the reduction of the cross-section of the structural element, which inevitably orients the development of concrete shrinkage in this position.

Depending on the calculated values of the shrinkage in concrete, the tube of adequate size may be selected.
Because the effect of the shrinkage of concrete is maximal at the position where the element (wall) stiffness is smaller and this stiffness is further reduced due to tube placement, also at this position mainly the static impacts are maximal on the opened buildings such as water retaining structures, then it is advisable to analyze the wall in calculation as a cantilever which requires larger dimensions but this is usually not a problem for water retaining structures which, due to other aspects, also acquire larger dimensions. While in buildings where walls have a statical system of bottom and top connection (such as basement walls, slabs, etc.) generally no increase in element thickness is required.

Advantage of the use of joint tube for induction of cracks

Selection of the design of reinforced concrete liquid retaining structures with controlled cracks has several advantages compared to the design with cracks limitation or without cracks, including:

1. Provides complete safety to eliminate leakage,
2. Cracks are controlled and the possibility of cracks appearance in other positions of the structural elements is eliminated,
3. It is a very economical solution (smaller element thickness and smaller amount of reinforcement),
4. Easy to apply and maintain, etc.

When applying this concept, appropriate measures must be taken to fully achieve its intended purpose by applying the recommendations given in EN 1992-3, among others:

- Must have proper sealant material selected for filling gaps at induced crack depending on the liquid to be retained,
- Sealants to joints must be constructed in such a way as to enable inspection, maintain and easy repair or renovation of them.

Conclusions

With the application of joint tubes for induction of joints in the abovementioned facilities no cracks have been appeared in any other position on the walls of the buildings, ie the effect of the shrinkage of the concrete has been successfully taken by tube, thus ensuring no leakage of facilities, respectively is reached the purpose of their application.
Also, at the pipe contact with the water-stop tapes there is no leakage which means that even at these positions waterproofing has been fully achieved.
As the concrete begins to harden, cracks begin to appear at the place where the pipe is laid and passing the time this crack is increased to a normal expected level. Then the left joint is filled with the recommended flexible mortar and then the facility is tested for leakage in which no leakage is shown to the positions where the joint tube for induction of cracks was used. In this project, the joint tube for induction of cracks was also used in horizontal position on the cover plate of the accumulation tank due to the large amount of concrete that this plate had, and also in this case it was achieved to eliminate the effect of concrete shrinkage and not allowing cracks to appear in unwanted positions.
From the lessons we have learned from the practical use of this concept in the above mentioned project as well as at other buildings, we recommend applying it to basement floor of buildings or at other buildings in contact with wet ambient as it is a safe concept for eliminating the

shrinkage effect in concrete which, if not treated with enough care can cause severe damage which are very difficult and very costly to repair.

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