MINISTRY OF EDUCATION AND TRAINING MINISTRY OF CONSTRUCTION

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LE THAI BINH

WORK OF THE ROAD INTERIOR CEMENT CONCRETE CURING IN VIETNAM CONDITIONS

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INTRODUCTION

*** The necessity of the thesis**

CONCRETE CEMENT pavement is heavily influenced by maintenance work. CONCRETE maintenance has been around for a long time and the usual method that we use is to add water to the CONCRETE surface or cover to minimize the influence of climatic factors on the CONCRETE. These methods are now becoming less effective for CONCRETE CEMENT used for motorways and airports. On the other hand, at the construction site, maintenance of CONCRETE from outside is not always easy, especially for structures with large open surfaces, construction in long lines, located in areas with difficult terrain. difficult, water resources are scarce. The fact shows that the maintenance of pavement concrete is an important task, but little attention is paid to it, especially in difficult terrain areas without water or rare water sources. Maintenance is therefore quite expensive and difficult to ensure regulations. The quality of the existing concrete pavement structure is often degraded due to maintenance reasons. The solution of curing CONCRETE with internal water, through the ability of some materials to absorb and retain water, is called Internal Curing (IC). The internal maintenance method meets the simple implementation of CONCRETE maintenance, does not affect the intensity of the CONCRETE and reduces the cost of external maintenance.

The use of IC means adding a quantity of water-retaining material to the CONCRETE CEMENT mix, which is effective in reducing shrinkage, limiting cracking during strength formation. However, it is also possible to change the working of the pavement structure with the criteria of compressive strength, tensile strength in bending, modulus of elasticity, coefficient of permeability, abrasion ... which certainly need research has clarified. Therefore, the topic *"The work of internal maintenance concrete pavement pavement in Vietnamese conditions"* was conducted, contributing to demonstrate the possibility that using internal maintenance solutions in concrete can improve many properties of the concrete. MIXCONCRETE and evaluate the possibility of using internal maintenance concrete for road pavement construction in Vietnam.

* Objectives of the study

Researching internal maintenance concrete for road pavement construction in Vietnam's climate in order to achieve the following objectives: Designing composite components and evaluating basic physical and mechanical parameters of internal maintenance concrete to meet the technical requirements of CONCRETE CEMENT as road surface; Evaluation of the ability to perform internal maintenance of CONCRETE CEMENT designed for automotive pavement application; Evaluate the basic behaviors of interior-maintained concrete when being applied as a road pavement concrete, thereby highlighting the ability and scope of application of internal-maintenance concrete for road pavement construction. in Vietnam's climate.

*** Object and scope of the study**

- Research object: CONCRETE CEMENT road surface using internal maintenance CONCRETE to meet the requirements for motorways with conventional construction technology.

- Scope of the study: Research on using a mixture of keramzit light sand and finely milled XLC for internal maintenance concrete towards the application for concrete pavement construction in Vietnam conditions (from grade III and below).

*** Thesis structure**

Consists of an introduction, followed by 4 chapters, conclusions, recommendations and future research directions, published scientific works, list of references and appendices.

*** Scientific and practical significance of the thesis**

- Scientific significance: The thesis has contributed to confirm the scientific hypothesis of the thesis as "The road surface of automobiles uses internal-cured reinforced concrete with water-saturated light sand combined with fine-grained XLC, ensuring strength required compressive strength, improve the tensile strength in bending and shrinking; suitable for road surface grade III and below”. The study has clarified more about the characteristics and properties of MIX CONCRETE and CONCRETE using light sand separately, using light sand in combination with XLC. From there, an appropriate solution is proposed to improve the crack resistance for CONCRETE CEMENT for road application for specific road grade.

- Practical significance: Research results have shown that it is possible to use light sand to manufacture internal maintenance concrete that meets the technical requirements for concrete for road construction. When combining XLC with light sand as internal maintenance material, it is possible to manufacture internal maintenance concrete to meet the technical requirements for CONCRETE CEMENT up to grade III pavements, according to the current CONCRETE CEMENT pavement design guidelines in Vietnam. . From the experimental research results of internal maintenance CONCRETE CEMENT using light sand combined with XLC to meet the requirements of pavement works, structural analysis has been performed to apply the material in actual road traffic works.

*** New contributions of the thesis**

- Choosing a reasonable amount of light sand as the material for internal curing CONCRETE with finely ground XLC mineral additive.
- Determine the reasonable mortar residual coefficient range for compressive strength, tensile strength when bending and abrasion of internal curing concrete to meet the technical requirements for CONCRETE CEMENT for roads to grade III.
- The work of internal maintenance concrete has been determined in the road surface structure.
- Research results are used to audit the calculation standards of pavement structure using internal maintenance CONCRETE for traffic pavement.

*** Terms**

"CONCRETE CEMENT road surface" – is the road surface structure using CONCRETE CEMENT. "Internal curing concrete" – is the CONCRETE that uses water-retaining materials to provide water from the inside for the hydration of cement when the concrete forms strength.

CONTENT

CHAPTER 1. OVERVIEW OF RED ROAD CONSTRUCTION AUTOMATS USE CONCRETE CEMENT INTERNAL MAINTENANCE

1.1. Road surface CONCRETE CEMENT

CONCRETE CEMENT road surface appeared in the late 19th century, also known as hard road surface along with soft road surface, are the two main types of pavement used for road traffic and airports, playing an important role in shaping the road surface. form the transport network of Vietnam and many countries around the world.

Figure 1.1. Road surface CONCRETE CEMENT

1.2. CONCRETE CEMENT internal maintenance

Internal curing (IC) is the process by which hydration of XM is continued due to the presence of internal water that is not part of the mixing water. The water supply to a newly set CKD mix is then used from storage tanks, such as water-saturated lightweight aggregates, to replace moisture lost through transpiration or auto-drying. The effect of internal curing on CONCRETE is shown as: Reduce spontaneous shrinkage and early age cracking; Reducing cracking due to plastic shrinkage; Increase intensity; Reduce the modulus of elasticity; Improved transition zone microstructure…

1.3. Studies on internal maintenance and application research in concrete pavement construction

**** Researches on internal maintenance concrete in the world***

The basic premise of IC was first recognized in 1957 and directly proposed in 1991. Subsequently, IC was widely studied in Germany, Israel, Denmark and the United States from the mid-1990s. of the last century to the present. Studies refer to common “water tanks” as LWAs, super absorbent polymers, and wood fibers.

**** Studies and use of internal maintenance concrete in Vietnam***

Vietnam's climatic conditions affect the CONCRETE work. Vietnam's climate belongs to the tropical, monsoonal climate zone, which is basically hot and humid and changes with distinct seasons and regions. The natural moisturizing process is divided into 2 stages: initial maintenance and subsequent maintenance.

Figure 1.2. Internal maintenance CONCRETE CEMENT road surface

Figure 1.3. External maintenance (EC) pavement CONCRETE CEMENT

Currently, our country also has research topics on internal maintenance in concrete using highly absorbent materials. In particular, the author Nguyen Duy Hieu is one of the pioneers in this field, and at the same time provides the scientific basis as well as the mechanism of water transfer in internal maintenance CONCRETE.

1.4. Issues that need to be researched and solved in the thesis

The thesis focuses on researching the following contents: Research on the scientific basis of the internal maintenance regime of concrete for concrete pavement; Research selection of input materials; Research and select distribution of internal maintenance equipment; Research on water loss, soft shrinkage, dry shrinkage and crack resistance of CONCRETE; Research some other properties of CONCRETE: strength development of CONCRETE over time, elastic modulus, water repellency, abrasion resistance, water absorption; Studying and calculating the internal maintenance of reinforced concrete structures for pavements.

CHAPTER 2. RESEARCH OF THE SCIENTIFIC BASIS OF CONSTRUCTION OF CAR ROAD SURFACE USE INTERIOR MAINTENANCE CONCRETE CEMENT

2.1. Scientific basis for construction of reinforced concrete pavement using internal maintenance concrete and the role of components of internal maintenance concrete

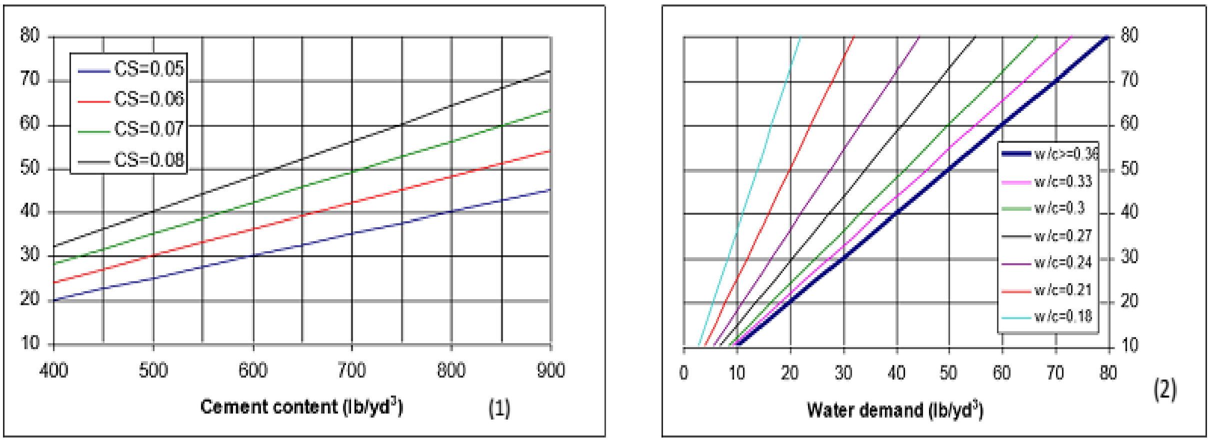
**** Basic material composition***

Component materials used in internal curing concrete include: XM, finely milled XLC, Small Aggregate, Internal Curing Material, Large Aggregate, Additives, Water all satisfy the technical requirements. according to Vietnamese standards.

**** Light sand in internal maintenance concrete for pavement***

Hollow aggregate (LWA) keramzite is a porous material formed by calcination mineral calcination (clay, clay, shale of all kinds, trepenite, diatomaceous earth, arginite, alevrolite) used as an aggregate for processing. create CONCRETE. LWA is a lightweight stone, a factory-made product. The raw materials are shale, clay or shale, fired in a rotary kiln at a temperature of >10930C. The softened material swells like a bubble structure. After cooling, the swelling state is maintained. The basic principle of IC is to keep the relative humidity in the pores of the binder rock, with a low water-cement ratio, always in a state of saturation; From the point of view that the volume of water stored by the CLR will offset the chemical shrinkage of the binder, it is possible to determine the amount of CLR (with a given porosity).

ACI standard (308-213)R-13 has shown a method to determine light sand content in internal curing concrete according to the graph.



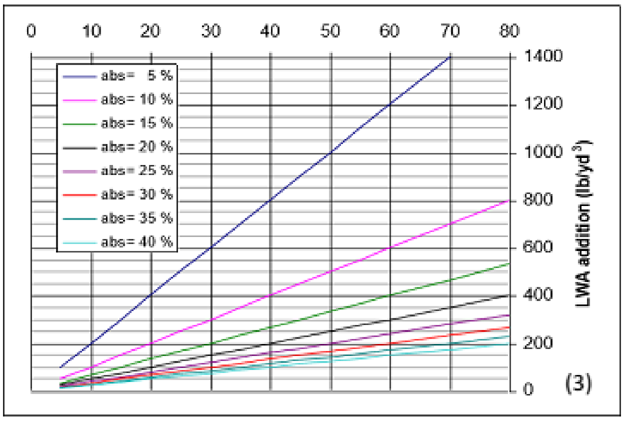


Figure 2.1. Determination of light sand content in internal curing concrete according to the graph

Theoretical basis and experimental research show that the amount of water contained in the pre-saturated hollow aggregate has the ability to move and penetrate to promote the game of shrinkage, maintain moisture to promote hydration. ensure the CONCRETE curing role in the strength formation process. This is the basis for proposing the study of using internal-maintenance concrete as a road surface and the basis for studying and proposing methods of calculating design and construction process of self-maintaining concrete pavement.

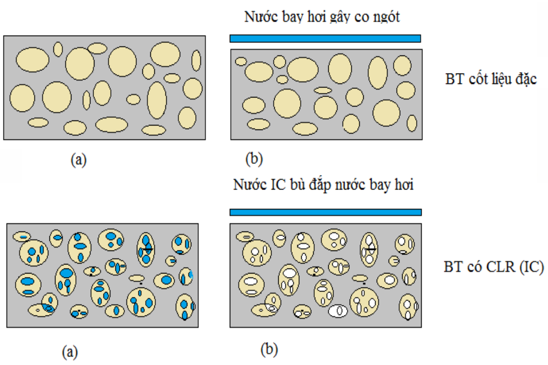


Figure 2.2. Model of the rehydration role of IC

According to preliminary calculations, the distance of water penetration from CLR into XM rock in CONCRETE reaches about 20 - 30 mm at the age of 3 - 14 days, 5-8 mm at the age of 28 days and about 2 - 4 mm at the age of 56 - 90 days. This result shows that IC water can penetrate most of the binder rock area in the concrete if the distance between the particles of the aggregate or the mortar residual coefficient of the concrete can be controlled.

It can be concluded: Internal maintenance is a scientifically sound solution, explained on the basis of analysis of physicochemical processes and material exchange occurring in the CONCRETE and between the CONCRETE and the environment through modeling.

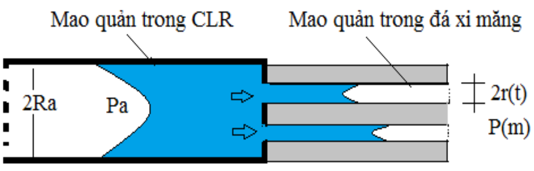


Figure 2.3. Laplace (Laplace) sub-pressure model

The amount of water contained in the pre-saturated CLR particles will shift to the binder rock bed in the CONCRETE, play the role of compensating shrinkage, maintain saturated moisture in the pore system of the XM rock, and promote the hydration of the rock. adhesive… that is, will promote the effect of internal curing.

**** XLC light sand combination in internal maintenance concrete for concrete pavement***

XLC is one of the high volume industrial waste products. XLC can also be used as a mineral additive to replace part of XM or part of aggregate in CONCRETE fabrication. XLC used as aggregate for CONCRETE is slag oConcreteained after slow cooling of liquid slag in air. This slag is granular, has a crystalline structure, is dense and therefore inactive. When used as aggregate, the slag is crushed and classified into the required grain grades. The results showed that when the granulated XLC was added to partially replace the XM with reasonable content, the strength, water separation, and waterproofing level of slag CONCRETE were improved compared to the control CONCRETE sample. When combined with light sand, the harmful effects such as water separation and reduction of CONCRETE strength at an early age due to the use of slag will be eliminated or reduced, on the other hand, because light sand has large porosity and good water holding capacity. should reduce water separation. Using XLC in CONCRETE is particularly beneficial because it replaces a relatively large amount of XM without adversely affecting CONCRETE intensity. Therefore, it is possible to use a large amount of binder in CONCRETE while ensuring that the amount of XM is kept at a low level.

**** Additives in internal maintenance concrete for pavement CONCRETE CEMENT***

In CONCRETE, mineral additives and superplasticizers are used to improve the properties of CONCRETE CEMENT.

2.2. Reduce water loss, shrinkage of internal maintenance concrete for road surface CONCRETE CEMENT

**** Hydrolysis of XM***

XM after being mixed with water goes through 3 stages. First, in about 1-3 hours after kneading, it forms a kind of slurry, easy to shape, then begins to set, the mixture gradually thickens but gradually loses its plasticity but not great strength. This phase ends in 5-10 hours after kneading, the mixture turns from a thick to a solid state, which means the end of setting and the beginning of solidification. The hardening phase is characterized by a rapid increase in strength.

**** Shrinkage of CONCRETE***

CONCRETE suffers a considerable deformation especially in the early age, most of these deformations occur in the mortar due to water loss to the environment or to chemical reactions, however aggregates also contribute. to the above deformations due to its physical properties and chemical composition. The process of contraction of CONCRETE can be divided into two phases: soft contractility and spasticity. Softening is contraction while CONCRETE has just been mixed in the early stages of setting. Spasticity or contracture is contraction when the CONCRETE has started to have a fairly high intensity. After the soft contractile phase, when the CONCRETE reaches the specified intensity, the contraction gradually decreases. Instead, it is dry contraction, due to loss of water in the pores. On the basis of the research results, the formula to calculate the shrinkage of XM according to the minerals of XM is as follows:

$$V_{cs} = 0.0532[C_3S] + 0.0400[C_2S] + 0.1113[C_4AF] + 0.1785[C_3A]$$

The cause of the endogenous contraction is related to the physicochemical processes occurring in the XM rock structure.

2.3. Reduced shrinkage of internal curing concrete for pavement CONCRETE CEMENT

Shrinkage or spasticity is a volume reduction phenomenon that occurs in low humidity environments due to evaporation of water on the surface of solidified concrete. The nature of spasticity is similar to that of flaccid contraction but occurs when the CONCRETE has solidified. The degree of spasticity depends on factors such as environmental conditions, N/CKD ratio, shape and size of CONCRETE structure,…

2.4. Shrinkage cracking and solutions to limit shrinkage - cracking in CONCRETE pavement

Cracks can appear on reinforced concrete structures due to many individual causes, and can also be caused by a group of causes combined. In general, the causes of cracking on reinforced concrete structures can be divided by physical factors and mechanical factors. The cause of cracking can be divided into: Crack due to soft expansion; Cracking due to hard deformation of CONCRETE; Cracking due to changes in ambient temperature; Cracking due to thermal effect…

2.5. CONCRETE pavement maintenance and influencing factors

Maintenance is especially important for pavement because compared to other types of concrete structures, concrete pavement has a high surface-to-total volume ratio of concrete. Poor maintenance can lead to CONCRETE pavement damage: damage occurs due to plastic shrinkage cracking, thermal stress or evaporative shrinkage cracking. Poorly maintained CONCRETE pavement may also have poor wear resistance and may not be able to resist the effects of salt on coastal roads, or the effects of other pavement degradation processes.

Maintenance of asphalt pavement after laying is a complex process and is influenced by many factors, controllable factors (composition and type of component materials used), and cannot be controlled but can only be minimized (temperature, wind speed, humidity), in addition determined by the rate of water separation and the onset of hardening, parameters that are also affected by many factors. many factors that may or may not be controllable.

Having a mixture with a self-maintenance mechanism, with a mechanism that automatically adjusts the water supply according to the water separation rate of the CONCRETE CEMENT and with the influencing factors will be a solution that is not only effective due to minimalism. Optimizing maintenance work that can completely control the risks of maintenance damage and ensure the strength formation of pavement concrete.

CHAPTER 3. EXPERIMENTAL RESEARCH OF CONCRETE CEMENT . MATERIAL

INTERIOR MAINTENANCE OF THE SURFACE OF CAR

3.1. Research content, research objectives and experimental methods

**** Basic criteria of concrete pavement for pavement and testing methods***

For the component materials of the internal curing concrete, the published standards are used to determine the mechanical and physical properties.

**** Technical specifications of the road surface CONCRETE CEMENT***

Technical requirements of concrete pavement according to Decision No. 3230/QD-BGTVT. Physical and mechanical parameters of concrete and optimal slump of MIXCONCRETE according to TCCS 40: 2022/TCDBVN.

**** Experimental research content***

Contents of experimental research with 30 aggregate grades denoted from CP1 to CP30 and 05 control grades as CONCRETE usually use fine aggregate which is heavy sand (yellow sand) denoted from CV1 to CV5.

3.2. Component materials of internal curing concrete in research

**** Materials composition and basic properties***

The materials used in the research were selected from natural, available and popular sources in the country. In the study used: Nghi Son XM PBC40; Finely milled XLC partially replaces XM; Small aggregate is yellow sand (CV - heavy sand) of Lo river - Viet Tri; The selected internal curing material is light sand oConcreteained from Dong Nai Light Stone Factory; Crushed stone with the largest particle size of 20mm is produced from Kien Khe limestone quarry - Ha Nam; Polycarboxylate-based superplasticizer; Hanoi tap water for mixing CONCRETE.

**** Selection of research components CONCRETE***

Using the method specified in Decision No. 778/1998/QD-BXD "Technical instructions for selecting CONCRETE components of all kinds", to design and select CONCRETE components. The thesis has conducted a preliminary survey of CONCRETE aggregates manufactured with the same type and amount of cement, approaching the principle that the amount of cement used in the mixes is minimal (300 kg/m3) and constant. XLC acts both as an additional binder and as an additional microaggregate to CONCRETE, with the amount used calculated at a ratio of 15% to 55% of the amount of XM. The amount of light sand calculated with the chemical shrinkage of the binder (CS) takes some value in the range 0.06 – 0.08. The test mixes are designed with different mortar residuals from 1.20 to 1.69. The thesis has selected the distribution levels used in the research as Table 3.1.

Table 3.1. Components of research papers

TT	**Symbol CP**	**Amount of material used, kg/m^3**							**Parameter**	
		XM	**XLC**	**Water**	**CN**	**Sand**	**Stone**	**PG**	**Rate XLC/XM**	**K_d**
1	CP1	300	0	136	202	472	1325	2,69	0%	1.20
2	CP2	300	0	136	219	511	1257	2,69	0%	1.33
3	CP3	300	0	136	235	547	1199	2,69	0%	1.45
4	CP4	300	0	136	249	581	1146	2,69	0%	1.57
5	CP5	300	0	136	262	611	1097	2,69	0%	1.69
6	CP16	300	105	136	176	411	1324	2,69	35%	1.21
7	CP17	300	105	136	193	451	1259	2,69	35%	1.33
8	CP18	300	105	136	209	488	1201	2,69	35%	1.45
9	CP19	300	105	136	223	521	1147	2,69	35%	1.57
10	CP20	300	105	136	236	551	1098	2,69	35%	1.69
11	CPV1	300	0	136	0	733	1322	2.69	0	1.21
12	CPV2	300	0	136	0	793	1254	2.68	0	1.34
13	CPV3	300	0	136	0	849	1194	2.68	0	1.46
14	CPV4	300	0	136	0	900	1140	2.67	0	1.59
15	CPV5	300	0	136	0	946	1090	2.67	0	1.71

**** Effect of mortar residual coefficient on the properties of internal curing MIXCONCRETE for pavement CONCRETE CEMENT***

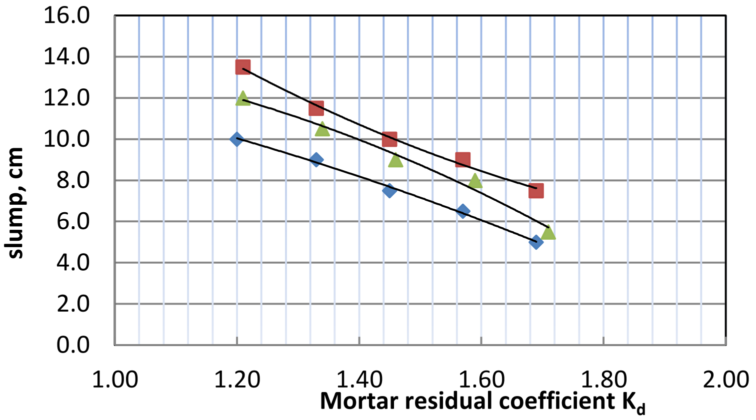


Figure 3.1. Effect of mortar residual coefficient on slump of MIXCONCRETE

Mortar residual coefficient shows the correlation between the volume of cement mortar with the volume of voids between large aggregate particles in MIXCONCRETE. The results show that with the same amount of mixing water and the ratio of water reducing admixtures, the slump of MIXCONCRETE in general tends to decrease when increasing the mortar residual ratio. This is explained that when increasing the mortar residual coefficient, the amount of sand in the MIXCONCRETE increases, causing the water requirement of MIXCONCRETE to increase, which causes the slump of MIXCONCRETE to be reduced.

The addition of replacement XLC to CONCRETE IC does not affect the workability as well as the degree of slump loss according to the mortar residual coefficients. It is shown in the results of the study that when increasing the mortar residual coefficient in the porous state without compaction from 1.20 to 1.71, for heavy sand (CV) the decrease is from 12.0cm to 5.5cm, for concrete IC (XLC/XM=35%) the drop is from 13.5cm to 7.5cm, for CONCRETE IC (XLC/XM=0%) the drop is from 10.0cm to 5.0cm. This proves that the use of light sand as internal curing material with the amount of XLC/XM=35% can be considered as a reasonable solution.

**** Ability to maintain the workability of internal maintenance CONCRETE mix for road surface CONCRETE CEMENT***

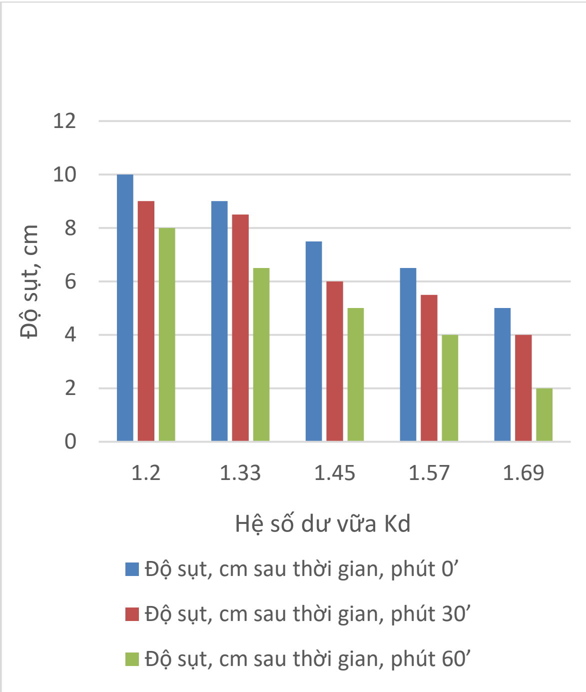


Figure 3.2. Decline in slump of internal maintenance CONCRETE mix without using XLC over time

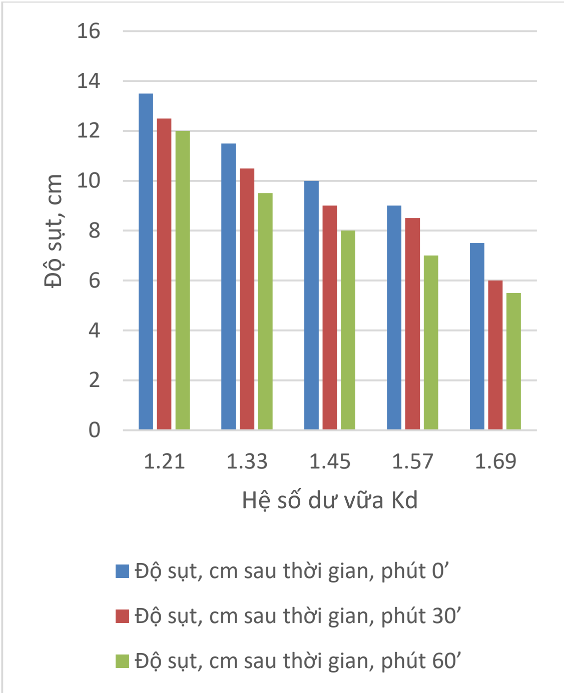


Figure 3.3. Decline in internal maintenance CONCRETE mix using 35% XLC over time

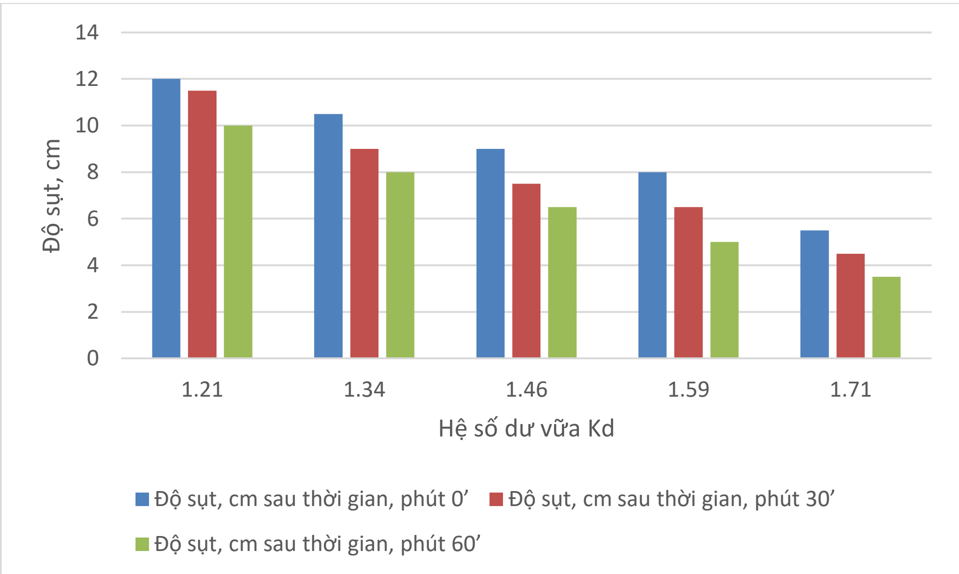


Figure 3.4. Decline in the decline of the control CONCRETE mix over time

Experimental results show that the CONCRETE mix have not much decrease in slump over time. It can be seen that after 60 minutes, the drop in MIXCONCRETE decreases over time by about (2÷3) cm. CONCRETE MIX IC with XLC 35% gave the lowest reduction (1.5 ÷ 1.8) cm compared with the decrease of 2.0 cm of normal CONCRETE CEMENT and (2÷3) cm of CONCRETE IC without XLC. However, with all these reductions in workability, the MIXCONCRETEs can still meet the construction requirements for CONCRETE CEMENT pavement. If you want to maintain the slump of the MIXCONCRETE to ensure the workability requirements in construction for the concrete pavement, it is necessary to use technological measures.

**** Stratification of internal maintenance MIXCONCRETE for road surface CONCRETE CEMENT***

In MIXCONCRETE, the phenomenon of stratification occurs when the components of MIXCONCRETE do not have uniformity but are separated in a certain direction, mainly in the direction of shaping. To study the stratification of internal maintenance MIXCONCRETE for concrete pavement, the test results are presented in Table 3.2.

Table 3.2. Experimental results of properties of MIXCONCRETE

TT	Symbol CP	K_d	KLTT, kg/m^3	Slump, cm	Air bubbles, %	Water separation, %	Mortar separation, %
1	CP1	1.20	2430	10.0	1.5	0.0	3.9
2	CP2	1.33	2420	9.0	1.6	0.0	4.1
3	CP3	1.45	2410	7.5	1.9	0.0	4.2
4	CP4	1.57	2410	6.5	2.1	0.0	4.3
5	CP5	1.69	2400	5.0	2.3	0.0	4.5
6	CP16	1.21	2450	13.5	1.1	0.0	0,0
7	CP17	1.33	2440	11.5	1.3	0.0	0,0
8	CP18	1.45	2440	10.0	1.4	0.0	0,0
9	CP19	1.57	2430	9.0	1.5	0.0	0,0
10	CP20	1.69	2430	7.5	1.6	0.0	0,0
11	CPV1	1.21	2490	12.0	1.2	0.0	0.1
12	CPV2	1.34	2480	10.5	1.5	0.0	0.3
13	CPV3	1.46	2480	9.0	1.6	0.0	0.5
14	CPV4	1.59	2470	8.0	1.7	0.0	0.7

TT	Symbol CP	K_d	KLTT, kg/m^3	Slump, cm	Air bubbles, %	Water separation, %	Mortar separation, %
15	CPV5	1.71	2470	5.5	1.9	0.0	1.2

The above results show that it is possible to use internal curing material which is light sand together with XLC (at the replacement rate of 35% XM) to meet the requirements of water separation of MIXCONCRETE for CONCRETE CEMENT pavement. When increasing the mortar residual coefficient from 1.20 to 1.71, with heavy sand (CV) the decrease is from 12.0cm to 5.5cm and the grout separation increases from (0.1÷1.2)%, with fine aggregate mixtures (heavy sand + light sand + 35% XLC) the drop from 13.5cm to 7.5cm and no grout separation has a value of 0%, and with small aggregate mix (heavy sand + light sand + 0% XLC) drop from 10.0cm to 5.0cm and grout separation increased from 3.9% to 4.5%

Thus, with the same ratio of X/N = 2.20, the grout separation tends to increase gradually with the increase of the mortar residual coefficient, the grout separation for heavy sand (CV) from (0.1÷1.2))%, with fine aggregate mixture (heavy sand + light sand + 35% XLC) grout separation does not occur with a value of 0%, and with small aggregate mixture (heavy sand + light sand + 0% XLC) mortar separation increased from 3.9% to 4.5%. On the other hand, for concrete pavement, the abrasion of concrete is a very important criterion, besides the phenomenon of mortar separation and water separation directly affects the top surface of the concrete pavement, that is, directly Next to the abrasion resistance of CONCRETE, from which it can be said that the use of a small aggregate mixture (heavy sand + light sand + 35% XLC) is a reasonable solution to ensure the technical requirements for the road surface CONCRETE CEMENT.

3.3. Empirical research, results, analysis and commentary

**** Compressive strength of concrete pavement using internal curing concrete***

The results of determining the technical parameters of CONCRETE are presented in Table 3.3.

Table 3.3. Test results of technical parameters of concrete

TT	Symbol CP	K_d	Technical indicators at the age of 28 days		
			R_n, MPa	R_{ku}, Mpa	ĐMM, g/cm^2
1	CP1	1.2	31.4	3.35	0.78

2	CP2	1.33	32.3	3.59	0.81
3	CP3	1.45	33	3.75	0.7
4	CP4	1.57	32.6	3.99	0.83
5	CP5	1.69	30.9	3.84	0.87
6	CP16	1.21	34.6	4.77	0.41
7	CP17	1.33	35.4	5.15	0.43
8	CP18	1.45	36.5	5.57	0.4
9	CP19	1.57	35.6	5.85	0.47
10	CP20	1.69	33.9	5.69	0.49
11	CPV1	1.21	32.1	3.58	0.7
12	CPV2	1.34	32.8	3.86	0.73
13	CPV3	1.46	33.9	4.17	0.67
14	CPV4	1.59	33.2	4.38	0.75
15	CPV5	1.71	31.3	4.27	0.79

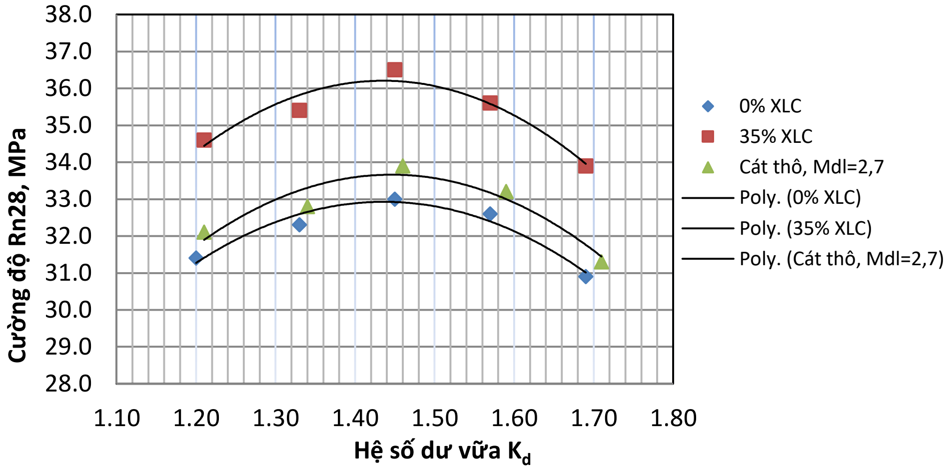


Figure 3.5. Effect of mortar residual coefficient on compressive strength of concrete

Through the chart, it is found that: (i) CONCRETE IC with 35% XLC has superior compressive strength (about 10%) compared with normal concrete mix and CONCRETE IC without XLC, corresponding to all mortar residual coefficients. and at all three ages; (ii) There exists a range of values of mortar residual coefficient for the maximum compressive strength. The range of mortar residual coefficient from 1.22 to 1.56, is the optimal grout residual coefficient range for the compressive strength of concrete used (heavy sand, light sand + heavy sand, light sand + heavy sand + XLC) . When the mortar residual coefficient increases, the compressive strength of concrete tends to decrease. Therefore, it can be seen that the increase of mortar residual coefficient has a negative effect on the compressive strength of internal curing concrete.

**** Tensile strength when bending of reinforced concrete pavement using internal curing concrete***

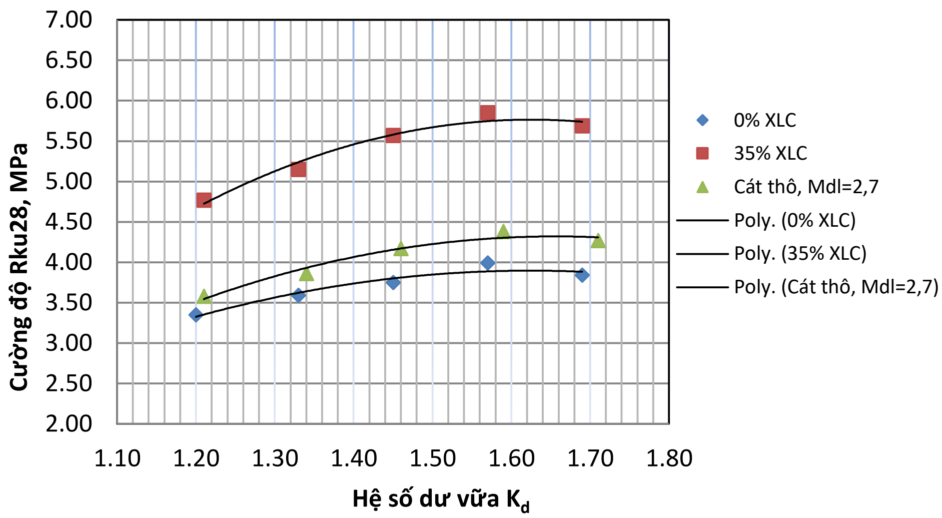


Figure 3.6. Effect of mortar residual coefficient on flexural tensile strength of concrete

When the residual coefficient increases from 1.20 to 1.59, the tensile strength in bending of concrete tends to increase gradually. When continuing to increase the mortar residual coefficient beyond 1.57, the tensile strength when bending of concrete tends to decrease. The difference between the maximum and minimum value of tensile strength when bending CONCRETE does not exceed 2 MPa. In the range of mortar residual coefficient from 1.47 to 1.68, MIXCONCRETE using light sand + heavy sand + XLC has the best workability, CONCRETE achieves the highest tensile strength in bending, or in other words the system range mortar balance from 1.47 to 1.68, is the optimal grout balance for the flexural tensile strength of concrete used (heavy sand, light sand + heavy sand, light sand + heavy sand + XLC) . When the mortar residual coefficient increases, the tensile strength in bending of concrete increases.

**** Abrasion of concrete pavement using internal maintenance CONCRETE***

The influence of mortar residual coefficient on the abrasion of internal curing concrete for concrete pavement is shown in the chart Figure 3.7.

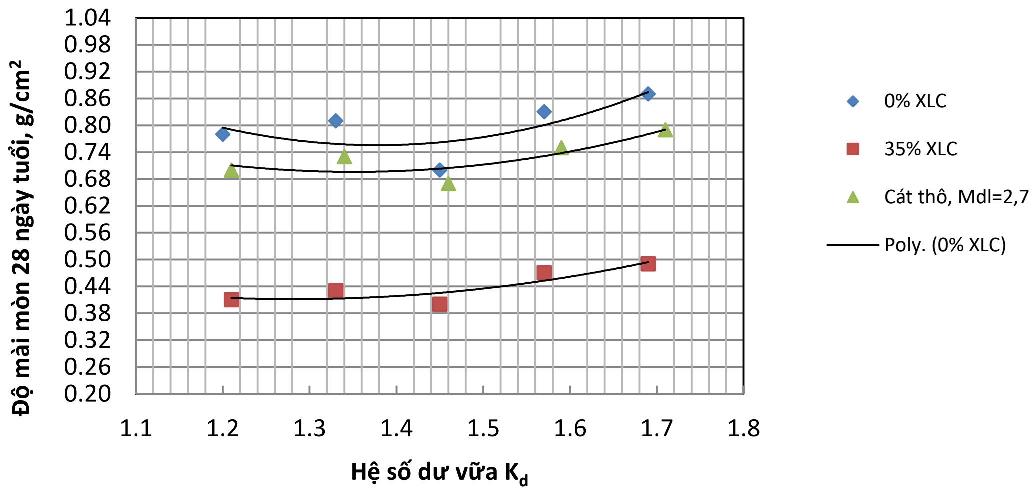


Figure 3.7. Effect of mortar residual coefficient on the abrasion of concrete at the age of 28 days

Evaluation of the trend of the relationship curve between abrasion and mortar residual coefficient, can see the similarity with the relationship between strength criteria and mortar residue.

**** Selecting the range of mortar residual coefficient for compressive strength, flexural tensile strength and abrasion for concrete for pavement CONCRETE CEMENT***

Mortar residual coefficient has a clear and quite close relationship with strength indicators: compressive strength; tensile strength in bending; and abrasion. The trend and value range of mortar residual coefficient corresponding to the highest strength and minimum abrasion of 03 types of CONCRETE (normally; CONCRETE IC without XLC, CONCRETE IC with 35% XLC) are not as different as Table 3.4.

Table 3.4. About reasonable mortar residual coefficient of 03 types of test concrete

TT	Experimental criteria	Mortar residual coefficient, K_d
1	Compressive strength	1,22 ÷ 1,56
2	Tensile strength in bending	1,47 ÷ 1,68
3	Abrasion	1,20 ÷ 1,56

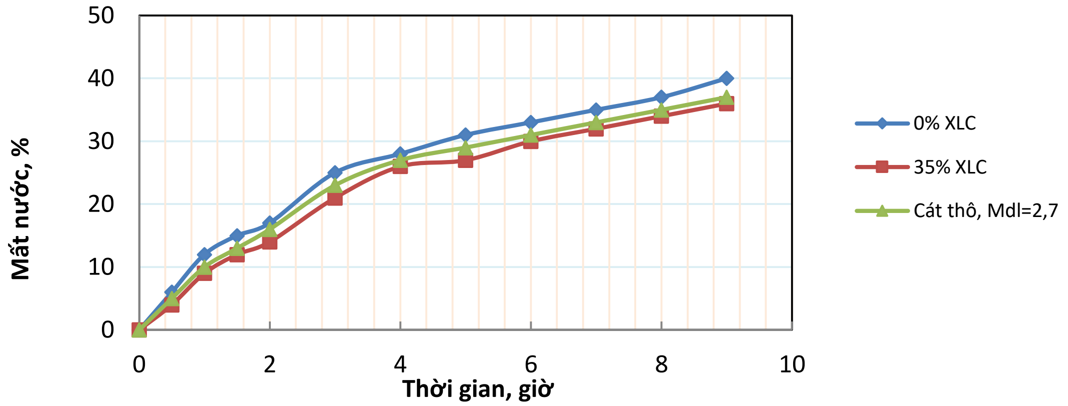
From the research results of intensity indicators and control experimental results of 03 types: normal CONCRETE; CONCRETE IC does not use XLC; CONCRETE IC uses XLC, there may be some preliminary comments as follows:

- CONCRETE IC with 35% XLC has superior strength compared to conventional CONCRETE CEMENT and CONCRETE IC does not use XLC with a minimum XM content of 300 kg/m3. This makes perfect sense because the addition of XLC will increase the total CKD content and improve the strength of CONCRETE CEMENT when replacing part of the fine aggregate (heavy sand) with light sand. The 28-day-old strength of CONCRETE IC with 35% XLC is completely capable of meeting the required strength and abrasion resistance of CONCRETE CEMENT pavement.

- CONCRETE IC with 35% XLC as well as 02 types of control CONCRETE have about mortar residual coefficient for the best strength (compressive strength, flexural strength and abrasion resistance). The reasonable combination of the grout residual coefficient values is (K_d = 1,47 ÷ 1,56).

**** Dehydration and shrinkage***

The dehydration and softening process of MIXCONCRETE and CONCRETE were also determined on a CONCRETE sample of size 100x100x400 mm with open modulus Mh=30 m-1, with the same experimental conditions as shown in Figure 3.8.



igure 3.8. Dehydration of MIXCONCRETE and CONCRETE over time, M_h=30 m^{-1}

Experimental results show that both types of CONCRETE IC and CONCRETE usually lose water quickly in the first (2÷4) hours, specifically to (14 ÷ 17) % in the first 2 hours and (26 ÷ 28) % calculated. in the first 4 hours. The shrinkage rate of 03 experimental types of CONCRETE is quite similar with the trend of rapid increase in the first 4 hours (about 0.35 ÷ 0.38 mm/m/hour), then very slow (0.03 mm/m/hour). hours and almost stopped.CONCRETE IC without XLC speed and total contraction in 9 hours is the largest.

The change of temperature and humidity during the experimental period of water loss and softening of MIXCONCRETE and CONCRETE are also monitored and presented in Figure 3.9 and Figure 3.10.

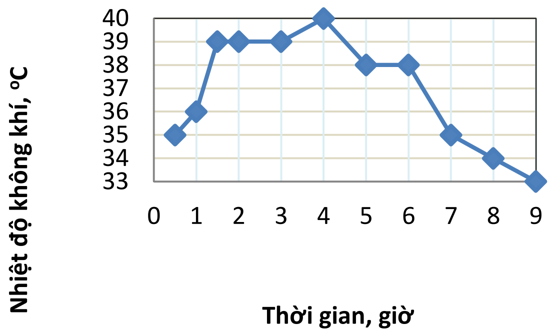


Figure 3.9. Temperature over time

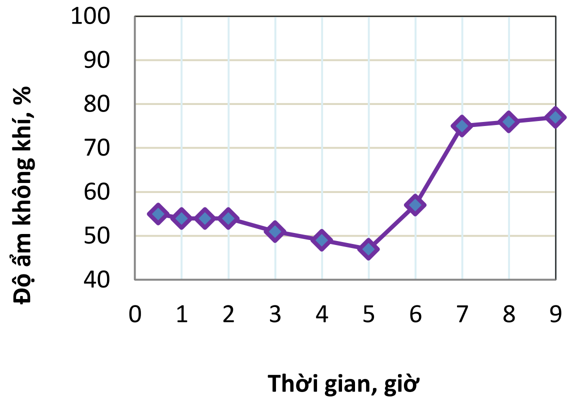


Figure 3.10. Humidity over time

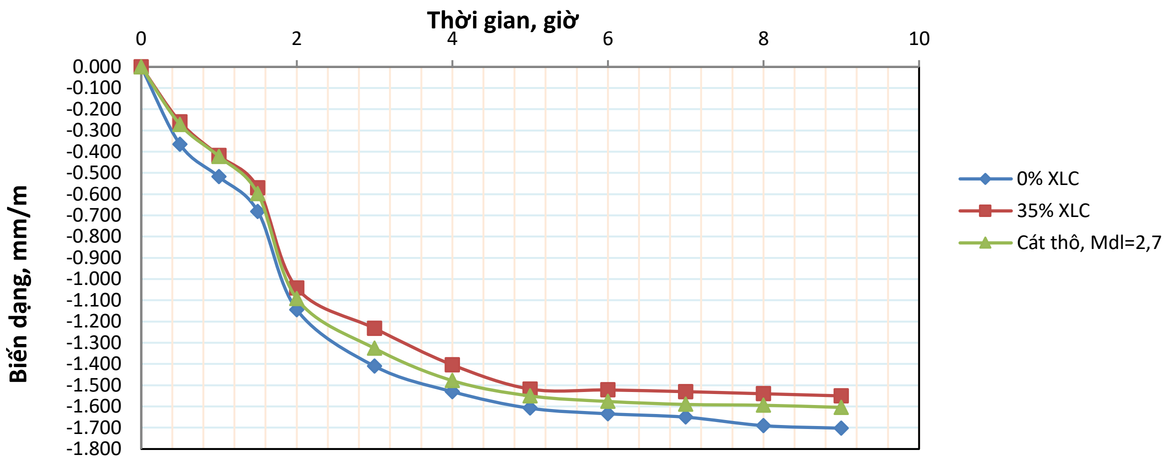


Figure 3.11. The process of soft contraction of CONCRETE over time, M_h=30 m^{-1}

It can be seen that the shrinkage of the CONCRETE used (light sand + heavy sand + XLC) is smaller in absolute value than that of 02 control types. This can be explained under the conditions of the same X/N ratio and XM use, the same open modulus Mh=30m-1 and the same experimental conditions, the small aggregate composition in the presence of XLC (35%) will make the mixture have a higher consistency, reduce the amount of water used and then the amount of free water in the MIXCONCRETE will increase, leading to reduced water loss and reduced shrinkage. Using XLC is a solution to slow down water loss, reduce shrinkage and limit cracking for CONCRETE IC.

**** Dry shrinkage of CONCRETE***

Under the same experimental conditions, all three types of CONCRETE tend to contract strongly during the first 28 days, and gradually decrease in the following days. The contraction almost stopped after 60 days. After 90 days, the shrinkage value is - 0.301 mm/m, respectively; - 0.284 mm/m; - 0.275 mm/m2 corresponds to CONCRETE IC without XLC; Regular CONCRETE CEMENT and CONCRETE IC with 35% XLC. It can be seen that the dry shrinkage of CONCRETE IC has 35% XLC which is smaller in absolute value. Thus, using XLC for CONCRETE IC helps to reduce shrinkage, and reduces the risk of cracking of CONCRETE IC when used as pavement..

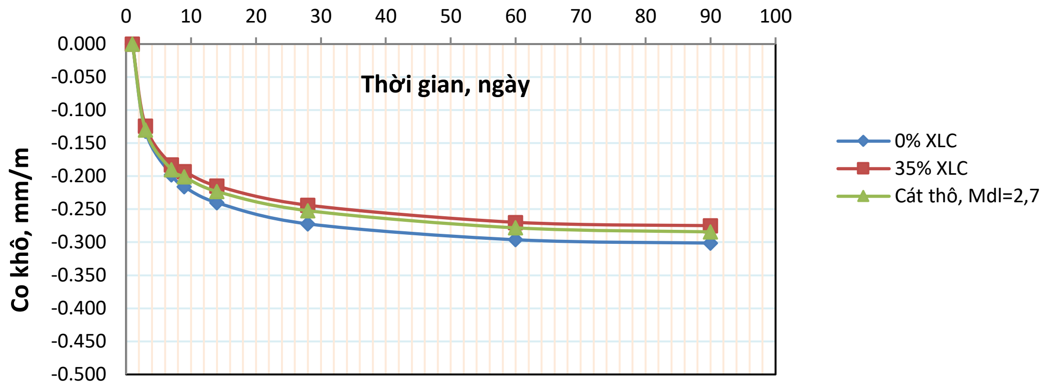


Figure 3.12. Shrinkage of CONCRETE over time

**** The waterproofing***

The test results in Table 3.5 show that the waterproofness of IC concrete with 35% XLC achieved B12 higher than the control samples B8 with CONCRETE IC without XLC and B10 with normal cement concrete. Using 35% XLC in small aggregate increases the density, leading to increased water repellency of concrete.

Table 3.5. Test results for the waterproofness of Concrete

TT	Symbol CP	XLC/XM	K_d	Waterproof level
1	CP4	0%	1,57	B8
2	CP19	35%	1,57	B12
3	CPV4	0	1,59	B10

**** Elastic modulus***

The elastic modulus of 03 types of CONCRETE were tested according to ASTM C469-10 with 28-day-old samples and presented in Table 3.6 along with the compressive and tensile strength of the samples.

Table 3.6. Test results of elastic modulus of concrete

TT	Symbol CP	XLC/XM	K_d	R_{ku28}, MPa	R_{n28}, MPa	Elastic modulus, GPa
1	CP4	0%	1,57	3,99	32,6	24,8
2	CP19	35%	1,57	5,85	35,6	27,5
3	CPV4	0	1,59	4,38	33,2	26,4

It can be seen that Internal curing concrete with 35% XLC gives the elastic modulus value in accordance with the technical requirements of the cement concrete pavement, corresponding to the compressive strength and tensile strength in bending.

Thus, the internal curing concrete with 35% XLC for higher strength indicators than the control types: normal cement concrete and IC without XLC with the same amount of XM used is the minimum for concrete. cement concrete for road surface (300 kg/m3). Tensile strength in bending, which is the most basic strength of cement concrete for pavement, of internal curing concrete with 35% XLC has superior performance compared to 02 control types, specifically higher 47% compared to normal cement concrete and 34% higher than internal curing concrete without using XLC. These strength values of IC with 35% XLC all meet the requirements of making cement concrete for pavement.

CHAPTER 4. APPLICATION OF INTERIOR CEMENT CONCRETE IN DESIGN AND CONSTRUCTION OF CEMENT CONCRETE Pavements IN VIETNAM'S CLIMATIC CONDITIONS

4.1. Study on thermal expansion coefficient of internal curing concrete

The coefficient of thermal expansion (CTE) of CONCRETE CEMENT is an important criterion, which is used in the calculation of concrete pavement in relation to thermal stress, plate size and expansion joint size. Referring to the results of foreign CTE research, with the research mixture using 40% light sand instead of small aggregate and 35% SF mineral additive, the suggested CTE coefficient is 7.0 microstrain/^{0}C.

4.2. Experimental study to evaluate the maintenance mode of CONCRETE IC

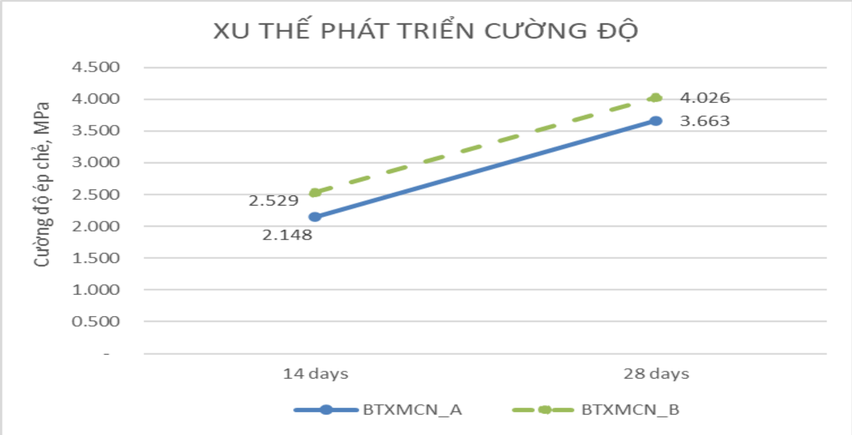


Figure 4.1. Strength development trend of concrete types

To test the self-curing ability of IC concrete, two curing modes are applied, namely curing mode A and curing mode B for typical IC concrete samples using light sand and 35% XLC calculated by weight of cement. Mode A follows the normal maintenance process of CONCRETE CEMENT: covered with a damp cloth and watered daily. Maintenance mode B: cover with a towel and water once after molding. The trend of strength development from 14 days old to 28 days old of all types of concrete with the studied maintenance regimes is shown in the graph Figure 4.1.

Based on experimental data, some observations can be made as follows:

- IC concrete cured in mode B (cloth coating, watered only once after casting) has a higher strength than that of fully cured specimen (cloth coating, daily watering), which is 17.7% for 14-day-old samples and 10% for 28-day-old samples.

- The trend in the graph shows that curing mode B does not affect the strength development ability of IC Concrete.

With the comments on the strength level achieved and strength development trend, the self-curing ability of IC Concrete can be clearly seen from the water contained in the light sand. From the research results, it is possible to propose a simple process of concrete pavement maintenance after pouring, with a solution of surface covering and watering once after placing and finishing the concrete surface.

4.3. Building the calculation problem of pavement structure Cement concrete using internal curing cement concrete materials according to AASHTO

**** Calculation data***

The expected pavement structure is as follows: - Self-curing concrete surface layer, thickness h = 26 cm (Tensile strength f_r = 5.5 MPa; Elastic modulus of material E_c = 27.5 GPa; Poisson's coefficient, due to the lack of experimental conditions, should be taken according to the usual CONCRETE CEMENT in the instructions μ_C = 0.15; Thermal expansion coefficient taken according to the mixture using crushed stone α_C = $7.0.10^{-6}$/°C); - CONCRETE CEMENT sheet size 4.8m x 3.5m (vertical slot with connecting rod; horizontal slot without connecting rod); - Upper foundation is made of XM 5% reinforced macadam with modulus h_b = 0.20m. recovery 600 MPa, Poisson's coefficient μ_b = 0.20; - The lower foundation layer is 0.18m thick crushed rock mix with elastic modulus equal to 300 MPa Poisson's coefficient μ_{sb} = 0.35; - Soil: Asia lightning at 0.65 relative humidity has E_0 = 44 MPa;

**** Traffic data calculation – design of rigid pavement structure according to AASHTO 1993***

According to the calculation method of AASHTO, with the corresponding expected parameters, the thickness of the Self-curing Cement Concrete slab included in the study is 23 cm respectively.

The 26 cm thick plate design satisfies the requirement with an excess of about 11%.

4.4. Auditing the pavement structure according to the current guidelines of Vietnam

Calculation of pavement structure Cement concrete using current design guidelines of Vietnam – Decision No. 3230/QD-BGTVT dated 14/12/2012.

**** Calculation data***

The interior-maintenance concrete mix is proposed to be designed for the district-level road, in Thanh Ba district, a mountainous district located in the northwest of Phu Tho province.

Calculation of car traffic in the 20th design year: 1707 xcqd/day and night, corresponding to grade IV road, mountainous terrain.

**** Traffic data calculation***

According to Guideline 3230, the amount of heavy traffic is calculated corresponding to 3000 vehicles investigated.

**** Calculation and design of hard pavement structure***

The expected concrete pavement structure consists of 26 cm of concrete surface layer on the 20 cm XM reinforced macadam foundation, 18 cm below the crushed stone foundation has achieved the allowable limit conditions, so the results can be accepted. This structure is the design structure. The corresponding excess in strength is 26.36%.

4.5. Structural testing by mechanical method – experimental damage prediction of pavement

Design method according to experimental mechanics using ME software, with limiting parameters at the end of the design period corresponding to 85% design reliability, including: IRI roughness: 2.7 m/km ; Percentage of panels showing horizontal cracks: 15%; Average length of damaged joint: 3mm.

The design input parameters put into the software include the following: Type of design; Type of pavement; Analysis period; Parameters of pavement cement concrete slabs; Parameters of upper and lower foundation; Climatic conditions parameters.

Calculation results: It shows that all parameters are achieved with damage prediction results in the 15th year as follows: IRI roughness forecast in the 15th year: 1.33 m/km; Percentage of panels showing horizontal cracks: 4.26%; Average length of damaged joint: 0.44 mm.

4.6. Conclusions on the application of internal curing cement concrete as concrete pavement in the conditions of Vietnam

With the basic contents done, the following conclusions can be drawn:

- The material satisfies the basic criteria and at the same time satisfies the design according to all 03 methods of designing the pavement structure Cement concrete (current design guidelines of Vietnam, AASHTO guidelines and mechanical software). experimental studies ME) for Cement-concrete pavement grade IV and below, with the average traffic volume for local roads from provincial roads and below.

- Research with 02 curing modes: normal procedure (A) and surface coating + watering once after application (B), shows that the trend of strength and intensity development in 14 and 28 days is not affected. The internal curing concrete specimen curing according to mode B gives improved split compressive strength compared to curing in mode A. Thus, Self-curing Cement Concrete can be constructed with a simple maintenance mode. , cost saving and suitable for local construction conditions.

- Construction steps for cement concrete pavement using internal curing concrete include: (i) Determination of the amount of light sand used for the construction shift; (ii) Lightly saturated sand soak for 24 hours; (3) Mixing, spreading and compacting CONCRETE according to the normal concrete pavement construction process; (4) Cover the surface with a suitable material to prevent water loss, water it once after application. To establish detailed construction procedures, field trials are required.

CONCLUSIONS, RECOMMENDATIONS AND PROPOSED DIRECTIONS FOR CONTINUED RESEARCH

Conclusion

Based on the research results achieved in the thesis, the following conclusions can be made:

- The amount of moisture kept in the porous structure of light sand is evenly distributed throughout the compacted mixture, allowing IC Concrete to self-regulate the curing process, not only simplifying the maintenance of Cement concrete pavement which is quite complicated. complex, but also has the ability to self-control the required amount of moisture supply in accordance with the water separation rate of the Cement Concrete. The thesis has demonstrated experimentally the advantages of "internal maintenance" compared to "external maintenance" according to the current conventional cement-concrete pavement construction process.

- Using XLC in IC Concrete contributes to improving the basic strength criteria of Cement Concrete such as compressive strength, tensile strength in bending, elastic modulus and abrasion resistance.

- Internal curing concrete using light sand + 35% XLC with minimum XM content as prescribed for Cement concrete for road pavement (300 kg/m3) with strength development as well as cost value of compressive strength, flexural tensile strength of Concrete at 28 days of age, abrasion meets the requirements of Cement-concrete pavement to grade IV.

- There exists a reasonable mortar residual coefficient for compressive strength, flexural strength and abrasion of IC Concrete to meet the technical requirements for concrete for road construction, especially for concrete pavement. Cement to grade III is equivalent to normal concrete, which is (Kd= 1.47 ÷ 1.56). This Kd value can be used as a reference when designing the IC Concrete component as a road surface.

- With the initial mechanical criteria determined in experimental research, with the corresponding set-up problem for a specific route, the design calculations of pavement structure according to 03 methods (instructions for the design of the road surface). Vietnam's current design, AASHTO manual and experimental mechanics software ME) all give satisfactory results.

- Experimental study with curing samples in 02 different modes: normal procedure (A) and surface coating + watering once after application (B), showing the trend of strength and strength development. degrees 14 and 28 days were not affected. Cement-cured concrete samples under mode B give improved split-pressing strength compared to curing in mode A. Thus, Self-curing Cement Concrete can be constructed with a simple and economical maintenance mode. cost-effective and suitable for local construction conditions.

- Proposing steps to construct Cement concrete pavement using IC Concrete: (i) Determine the amount of light sand used for the construction shift; (ii) Lightly saturated sand soak for 24 hours; (iii) Mixing, spreading and compacting CONCRETE according to the normal concrete pavement construction process; (iv) Cover the surface with suitable materials to prevent water loss, water once after application.

Proposing to continue in-depth research directions after the thesis defense

On the basis of the oConcreteained results, in order to continue to develop the research direction of Concrete using internal maintenance using XLC in practice, the thesis proposes the following in-depth research directions:

- Expansion of research on the service life of internal cement concrete pavement in different climates.

- In-depth study on the properties and bonding ability of the internal curing cement concrete layer with the Asphalt concrete pavement layer.

- Research and develop test application program.

PUBLISHED SCIENTIFIC WORKS

*** Scientific article**

1. Le Thai Binh, Tran Thi Kim Dang (2022), Experimental study results on strength indicators of internal maintenance concrete for automobile pavement; Transport Magazine (ISSN 2354-0818), September 2022.
2. Le Thai Binh (2022), Effect of mortar residual coefficient on tensile strength when bending of internal curing concrete for reinforced concrete pavement; Journal of Materials and Construction (ISSN 1859-381X), issue 04, volume 12, 2022.
3. Le Thai Binh, Nguyen Duy Hieu (2022), Effective internal curing of high strength cement mortar; Scientific Journal of Architecture and Construction (ISSN 1859-350X), No. 45/2022.

*** International Scientific Conference**

1. Nguyen Duy Hieu, Le Thai Binh, Truong Thi Kim Xuan (2019), Effect of internal curing on shrinkage and strength of concrete; International Conference on Architecture and Construction 2019 (ISBN: 978-604-67-1457-6), September 2019.