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EXPERIMENTAL STUDY ON RHEOLOGICAL BEHAVIOUR OF OLD AND NEW CONCRETE

Amir Ghafoor[*1], Ali Ajwad[2], Syeda Aqsa Jillani[3], Muhammad Naveed Khalil[4]

[*1]*College of Civil Engineering and Architecture, Henan University of Technology, Zhengzhou 450001*
[2]*Department of Civil Engineering, University of Management and Technology, Lahore, Pakistan.*
[3]*Department of Electrical Engineering, NFC Institute of Engineering and Technology, Multan 60000*
[4]*National Center of Excellence in Geology, University of Peshawar, Pakistan*

[*1]amir.ghafoor@gmail.com, [2]ali.ajwad@umt.edu.pk, [3]aqsajilani987@gmail.com, [4]geonaveed@uop.edu.pk

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Corresponding Author: *
Amir Ghafoor

Abstract
Replacement of cement concrete slab is one of the important measures for its maintenance after being used for several years. Due to structural differences between old and new cement concrete pavement slab, it is found that the old cement concrete slab has the tendency of accelerated damage in use. In this work, rheological behaviour of old and new concrete specimens is evaluated by obtaining C30 old cement concrete specimens drilled from a four (6) years old used cement concrete pavement with similar fresh cement concrete prepared specimens. One-time loading and cyclic loading and unloading tests were carried out by control displacement method on the old and new concrete specimens at 0.1mm/min, 0.3mm/min and 0.5mm/min loading speeds respectively. Rheological behaviour of cement concrete is characterized by the stress-strain curve variation law at three different rates. The rheological characteristics of cement concrete materials are explored by combining the test phenomena and the damage degree of the specimens in each test process. The experimental results show that the stress-strain curves of new cement concrete specimens grow linearly in a certain range (80% of maximum stress). The maximum stress of new concrete specimens increase linearly with the intensification of loading speed which indicates that cement concrete has certain viscous properties at different loading speeds and the cement concrete can be considered as linear elastic material when the change in slope of stress-strain curves is undeviating. Therefore, experimental study on the rheological properties of cement concrete is of great theoretical and practical significance for understanding the mechanical properties of cement concrete materials.

INTRODUCTION

Cement concrete pavement is one of the main structural forms of high-grade pavement due to the large bearing capacity, low maintenance cost and long service life [1]. Properties of fresh and hardened concrete are of great importance because of their effect on the construction quality for casting and the forming process [2]. The term of rheology was first proposed by Bingham in 1920. Concrete, cement paste and other cementitious materials are widely characterized by Bingham model for the study of their rheological behaviour [3]. Roussel [4] established a relationship between thixotropy of fresh concrete and its casting process providing a tool in order to foresee the formwork filling, multilayer casting occurrence and pressure formwork.. The behaviour of self-consolidating concrete used to model the flow of fresh concrete was described by Herschel-Bulkley [5]. Quality of constituents used in the concrete mix is not only the controlling factor for the quality of concrete structures but also depends on the rheological behaviour of concrete during the time of placement into the formwork [6]. The study of rheological properties mainly lessons the construction workability, consistency, flowability, mobility, pumpability, compactibility and finishability of fresh-mixed cement concrete. Static yield stress, dynamic yield stress and the plastic viscosity are the three properties to characterize the behaviour of fresh concrete as a fluid [7]. Transportation, placement, consolidation and formwork pressure are the properties of rheology which affect the rheological behaviour of concrete in its hardened form and long term behaviour of concrete [8].

Cement concrete is a highly heterogeneous material whose response to stress depends not only on the reaction of the components, but also on the interaction between these components. Research on the mechanical properties of concrete relies on experiments to determine its mechanical properties affected by factors such as the quality of the material, its composition, construction process and conditions of use [9]. In this work [10] laboratory testing was done the predict the effect of displacement rates and moisture contents on the strength of concrete at 0.05-0.25mm/min loading speed. The strength of wet specimens reduced with respect to dry specimens at the same displacement rates because the reduction in strength depends on the displacement rate. Concrete cracks during the hardening process if shrinkage is being restrained. Therefore the permeability of concrete rises due to the cracks produced in itself thus having reduced durability and an increase in leakage. Therefore, restrained shrinkage ring test was suggested in this study [11] to estimate the cracking sensitivity of concrete. Pulse velocity, pull of strength and compressive strength test of concrete were done in this study [12] to evaluate the mechanical properties and quality of hardened concrete with effect of mix design and formwork. Hardened concretes mechanical properties are correlated with the rheological properties of fresh concrete in the findings.

Several researchers [13-16] in an experimental campaign have studied the rheological properties of concrete and are more in-depth on the numerical simulation formulation of corresponding rheological models and their methods. Controlled displacement method can be set to most of the test frames as the grip displacement increases during the test procedure and the specimen will fail destructively at once when the applied load is no longer bearable [17]. Displacement control method is very useful for monitoring crack growth in the specimens or the decrease of stiffness in fatigue [18]. In order to assess the rheological characteristics of fresh and old concrete, stress-strain-strain curves are obtained by applying controlled displacement method to the specimens under one-time loading and cyclic loading and unloading tests.

MATERIALS AND EXPERIMENTAL METHOD

Materials

The location of drilling cores for old cement concrete samples is located in the rolling part of car and core samples are taken at an interval of 1m. The size of cement concrete slab of the road is 4m wide and 5m long shown in Figure 1. Therefore, ten (10) cylindrical cement concrete specimens were obtained on three cement pavement slabs. The cutting and grinding of old cement concrete specimens is carried out in the Highway Laboratory of Henan University of Technology. Concrete specimens were cut and grinded with 100 mm diameter and 150mm of length and were numbered as OLD1, OLD2..., and OLD10.

The designed strength grade of old cement concrete pavement was C30 and the standard compressive strength of cement used was 32.5MPa. It is difficult to directly prepare and ensure the properties of specimens with a length of 150mm and diameter of 100mm which can meet the design requirements. Therefore, ten (10) fresh concrete specimens were prepared by drilling cores like old cement specimens with a precast design strength of C30 150mm×150mm×150mm.

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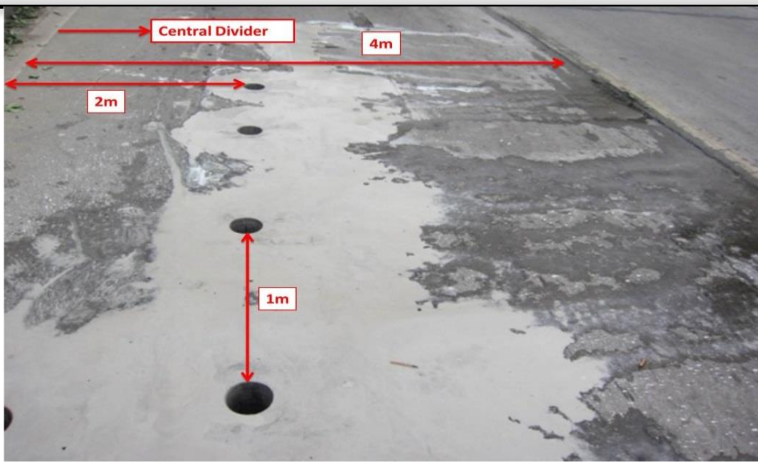

Fig. 1 - Schematic diagram of the specimen acquisition location

P.O32.5 Ordinary Portland Cement and coarse aggregate (crushed stone) with a diameter range of 3-30 mm were used in the preparation of mixture. Coarse aggregates were divided into four kinds: 3-5mm, 5-10mm, 10-20mm and 20-30mm and fine aggregate as natural river sand. Sand material is hard, clean and well graded with a fineness modulus of 2.5 known as medium sand. Whereas, the mixing water used is drinking water which conforms to the construction specifications.

The maximum water cement ratio and the minimum cement dosage of concrete are stipulated in the Code for Design of Mix Ratio of Ordinary Concrete (JGJ55-2000). The slump value of C30 cement concrete mixture designed by this test is 28mm. Compounding strength of concrete is 38.225 and the water cement ratio is 0.43. The maximum diameter of gravel is 31.5mm and the water consumption selected value is 180kg/m^3. The amount of cement used is 418.6kg/m^3 with a sand rate of 31%. The mixing of materials is carried out by a mixing machine with 60L capacity at one time. The mass of primary mixture was calculated to be 56.5kg with a mix ratio shown in Table 1 and Table 2.

Tab. 1 - Mix ratio for 60L capacity

'ater g)	ement g)	ınd g)	ravel g)
15	65	ŝ.66	).05

Tab. 2 - Gravel mix ratio for 60 L capacity

)-30 m (kg)	)-20 m (kg)	5-10 m (kg)	3-05 ım (kg)
23	ŝ.36	94	46

Concrete ingredients were mixed and new concrete samples were obtained. The prepared concrete specimens are fed into a standard curing room with a temperature of 20±2°C, humidity of 95% and the distance between specimens was kept as 10-20mm. After 28 days of curing, concrete test

piece of 150mm×150mm×150mm dimensions has the design strength of C30 cement concrete. The drilling process of the new cement concrete test specimens that meets the test requirements was done and the samples were numbered as N (New) 1, N2..., and N10.

Experimental method

The test operation is divided into two parts. First, one-time loading test of new and old cement concrete test pieces is carried out followed by cyclic loading and unloading test. Loading or unloading test with controlled displacement method is adopted in the whole test process, i.e. setting different loading rates to carry out the tests. Table 3 shows the mechanical test flow chart for old and new concrete specimens at different loading speeds. In order to determine and analyze the loading type, loading mode and loading rate; CMT5303 precision computer electronic universal testing machine manufactured by Sansi Company was used as shown in Figure 2.

CBY1 100-25 special clip-type extensometer manufactured by CRIMS (Changchun Machinery Research Institute Co., Ltd.) in Figure 3 was used for the measurement of deformation value of the test specimens. The bearing surface of the test piece is in good contact with the indenter and is set to be 0.05KN. The peak value of cyclic loading and unloading is set at 2/3 of the average failure pressure of the specimen as the range of loading and unloading force is 0.05KN-2/3F. The number of cycles is set to 5 times at 0.05KN-2/3F and the 6th time loading until the specimen breaks. Detailed mechanical test plan for new and old concrete specimens is shown in Table 4.

Tab. 3 - Mechanical test flow chart process for new and old concrete specimens

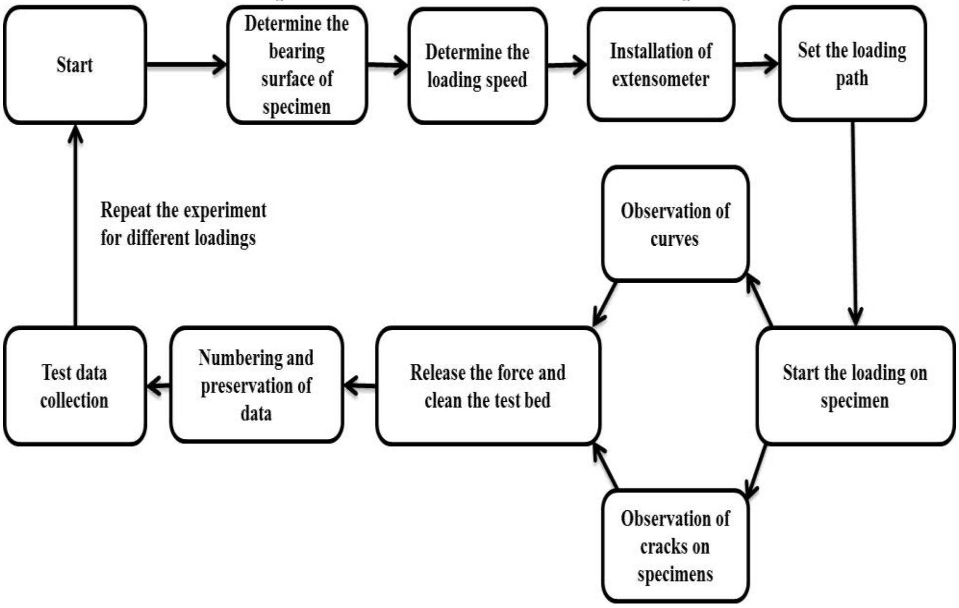

Fig. 2 - CMT5305 Universal Testing Machine

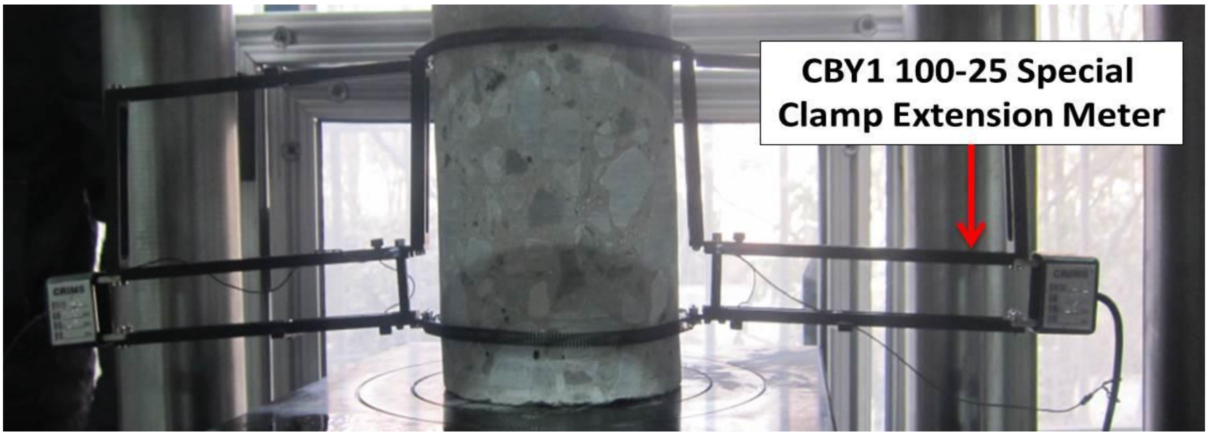

Fig. 3 - CBY1 100-25 Special Clamp Extension Meter

Tab. 4 - Mechanical test plan of specimens

ɔading Type	ɔading Speed (mm/min)	ata Record Form
ne-Time Loading	1	1-V0.1a, OLD1-V0.1a
	3	2-V0.3a, N3-V0.3a, OLD2-V0.3a, OLD3-ɔ.3a
	5	4-V0.5a, N5-V0.5a, OLD4-V0.5a, OLD5-ɔ.5a
yclic Loading and Unloading	1	6-V0.1b, OLD6-V0.1b
	3	7-V0.3 b, N8-V0.3 b, OLD7-V0.3 b, LD8-V0.3 b
	5	9-V0.5 b, N10-V0.5 b, OLD9-V0.5 b, LD10-V0.5 b

RESULTS AND DISCUSSION

One-time loading test

One-time loading test of the new cement concrete specimens is carried out at the rates of 0.1mm/min, 0.3mm/min and 0.5mm/min respectively. The average values of maximum load and failure load of the five specimens are shown in Table 5. The relationship between stress-strain curves for new concrete specimens is shown in Figure 4. When the loading rate is 0.1mm/min, the stress-strain curve is a linear growth process before 25MPa and after 25MPa the slope of the curve decreases until it reaches towards the failure. At the loading rate of 0.3mm/min, the specimens showed a linear growth trend before 27MPa and the slope of curve after 27MPa changed to 30.5MPa. At the loading rate of 0.5mm/min, stress-strain curve basically grows in a straight line before 36MPa and the slope decreases significantly after 35MPa.

Tab. 5 - Failure load and average values of new concrete specimens

ecimen type	1	2	3	4	5
ilure load	8.4KN	1.7KN	0.4KN	8.8KN	9.2KN
verage failure value			265.7KN		

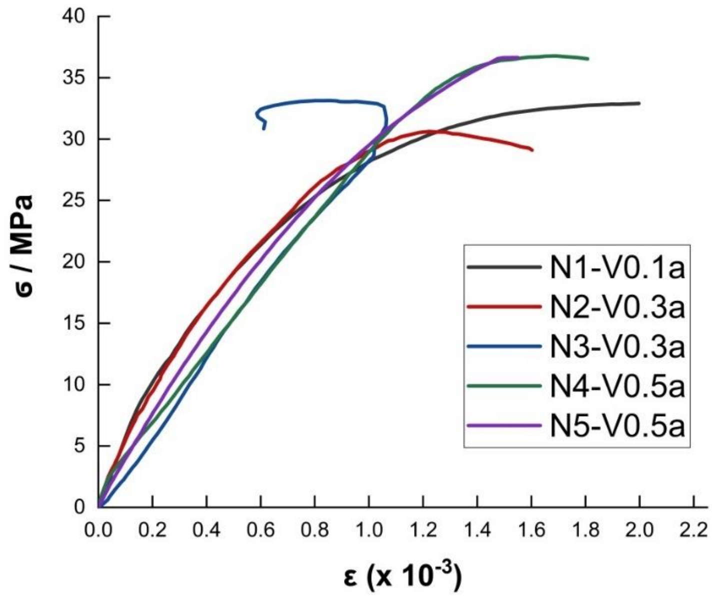

Fig. 4 - Stress-strain curves for one-time loading

Therefore, from the experimental data in Figure 4, it can be seen that the average maximum stress and strain of the three loading rates of newly prepared cement concrete specimens are 34MPa and 1.49×10^{-3}. When the loading stress is between 0-28MPa, the curves of specimens show a regular linear relationship and when the stress exceeds 28MPa, the slope of the stress-strain curves decreases obviously.

The stress-strain curves of different specimens at different speeds can be studied by analyzing the secant slope of stress-strain curves in different stress-strain ranges, that is, the secant modulus E_s of new cement concrete specimens. Table 6 shows the secant modulus E_s of each new specimen in one-time loading test according to different stress ranges and the curves of E_s with different stress ranges are shown in Figure 5.

Tab. 6 - Secant modulus E_s of new specimen in one-time loading test

; (×10^4MPa) /	1mm/min	3 mm/min		5 mm/min	
ress Range (MPa)	1	2	3	4	5
5-5	79	97	76	12	81
5-10	25	79	99	91	78
5-15	35	3	12	87	53

5-20	71	78	07	84	35
5-25	22	37	9	82	15
5-30	53	74	92	76	67
5-35				57	58
5- Maximum stress	64	62	1	14	35

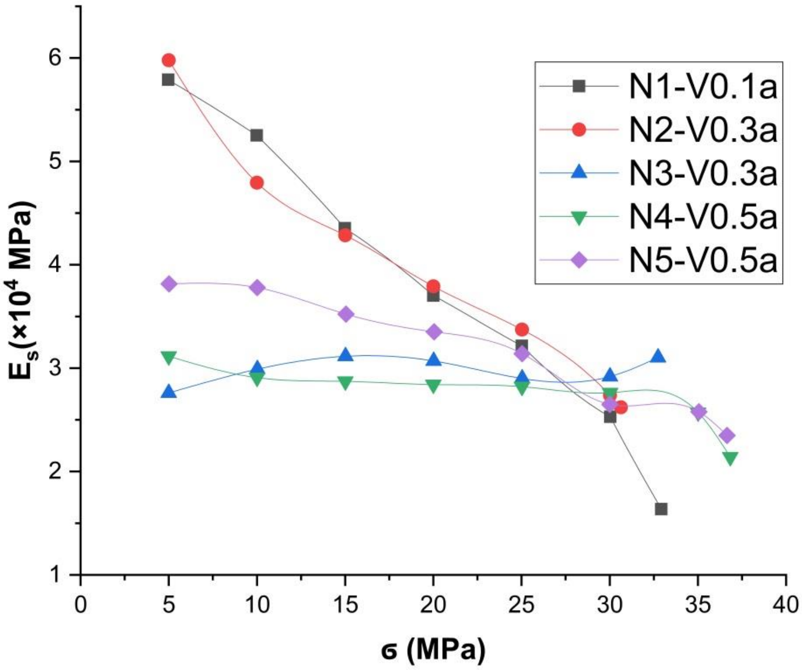

Fig. 5 - Curves of E_s with different stress ranges

According to different strain ranges, the Es values of each loading test are divided. When stress is 0.5MPa, the strain values corresponding to each specimen are about 0.006×10^{-3}, so the initial value of strain range is 0.006×10^{-3}. Table 7 shows the E_s values of each new concrete specimen in one loading test according to different strain ranges. The curves of Es with different strain ranges are drawn as shown in Figure 6.

Tab. 7 - E_s values of new concrete specimens at different strain ranges

$(\times10^4$MPa) / rain Range $(\times10^{-3})$	1mm/min	3 mm/min		5 mm/min	
	1	2	3	4	5
006-0.2	05	75	81	36	65
006-0.4	06	08	08	03	51
006-0.6	56	58	12	93	31
006-1.8	16	26	97	86	12
006-1.0	79	87	83	73	91
006-1.2	49	52		54	72

006-1.4	24			26	53
006-1.6	98				
006-1.8	8				
006-Maximum strain	64	62	1	15	36

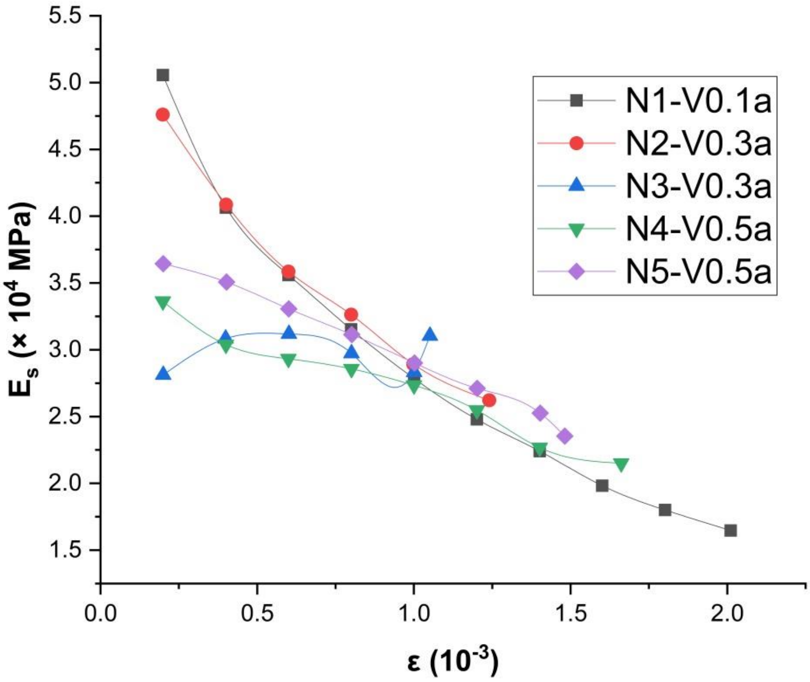

Fig. 6 - Curves of E_s with different strain ranges

In order to evaluate the mechanical properties of concrete specimens, it is necessary to study how the maximum average failure stress and secant modulus E_s of concrete specimens vary with different loading velocities speeds. The maximum stress and secant modulus E_c of each new concrete specimen under three different loading speeds are calculated as shown in Table 8. Whereas, the maximum stress-loading speed and E_s-loading speed analysis diagram of new concrete specimens is shown in Figure 7.

Tab. 8 - Average Maximum stress failure and secant modulus E_c

Loading Speed (mm/min)	Average Maximum Stress Failure (MPa)	verage Secant Modulus E_c (MPa)
0.1	32.9	$3.2×10^4$
0.3	31.7	$3.04×10^4$
0.5	36.7	$2.78×10^4$

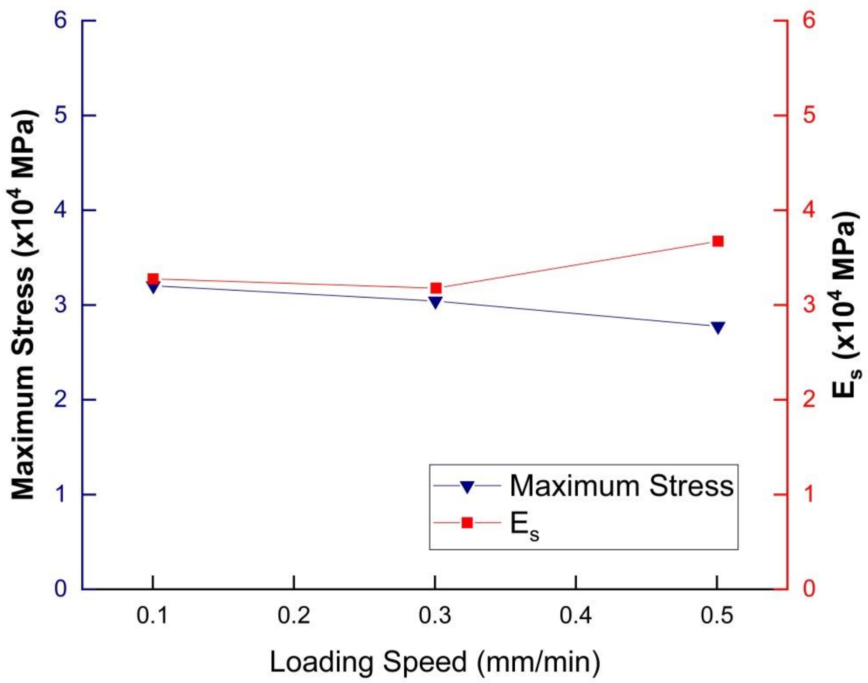

Fig. 7 - Maximum stress-loading speed & E_s-loading speed analysis of new specimens

Figure 7 shows that in one-time loading test of new cement concrete specimens, as the loading speed increases, the average fracture stress of the specimen variation are 5MPa. When the loading speed is increased, the average E_s of the test specimens slightly decreases to 0.4×10^4 which shows that different loading speeds produce small viscous deformation in the concrete specimens.

One-time loading test of the old cement concrete specimens is carried out at the rates of 0.1mm/min, 0.3mm/min and 0.5mm/min respectively. The average maximum failure load and failure load values of the five old concrete specimens measured are shown in Table 9.

Tab. 9 - Failure load and average values of old concrete specimens

Specimen type	OLD1	OLD2	OLD3	OLD4	OLD5
Failure load	101.8KN	130.8KN	161.5KN	105.2KN	144.6KN
Average failure value			128.8KN		

The OLD1 concrete specimen loaded at the speed of 0.1 mm/min has a maximum stress of 12.9MPa and a maximum strain of 1.18×10^{-3}. Figure 9 show that when stress reaches 9MPa, strain decreases as the stress is increasing. When the load is applied to the specimen, specimen starts to expand and micro cracks were produced at the measuring point of extensometer clamp as shown in the Figure 9. However, the specimen continues bear load and breaks completely until the stress reached 12.9MPa shown in Figure 10.

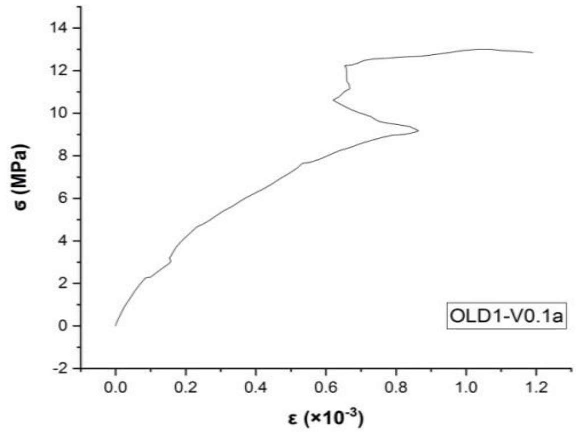

Fig. 8 - 0.1mm/min cyclic loading and unloading

Fig. 9 - OLD1 Specimen crack propagation

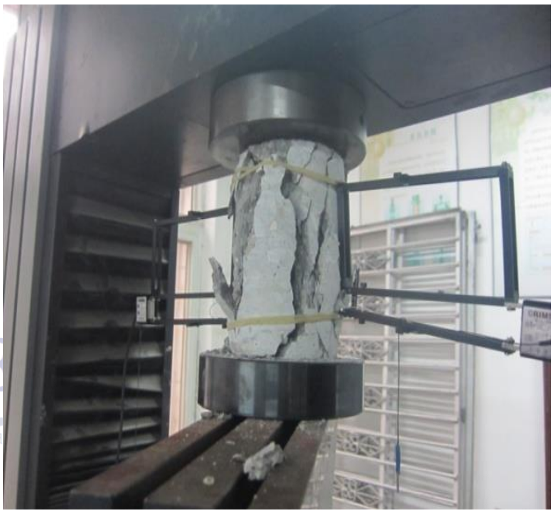

Fig. 10 - OLD1 Specimens failure

OLD2 and OLD3 specimens were loaded at the speed of 0.3mm/min. The maximum stress of OLD2 was only 8.6MPa with a maximum strain of 1.41×10^{-3}. The stress-strain curve generally shown in Figure 11 predicts an upward trend. As the old cement concrete specimen within itself had large cracks, when the stress reaches 4.8MPa, the existing cracks began to expand and stress continued to grow, which results in irregular stress-strain curve changes. When the stress reaches about 8.6MPa, the OLD3 specimen is completely destroyed.

OLD3 specimen's maximum stress is 21.1MPa with a maximum strain of 1.76×10^{-3} as shown in Figure 12. At the initial stage of loading, the stress-strain curve of the specimens increases linearly with a strain slope of straight line at $2.4\text{x}10^{4}$. When stress reaches 14MPa, instantaneous brittle failure occurs, resulting in larger longitudinal cracks, as shown in Figure 13. At this time, the stress intensity stops growing and has a slight downward trend when the strain continues to increase. When stress reaches 21.1MPa, the specimen is completely destroyed as shown in Figure 14.

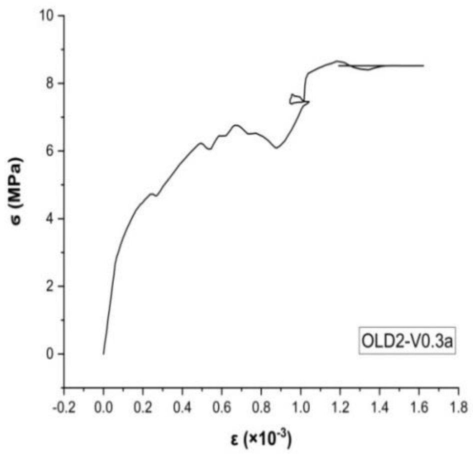

Fig. 11 - 0.3mm/min cyclic loading and unloading

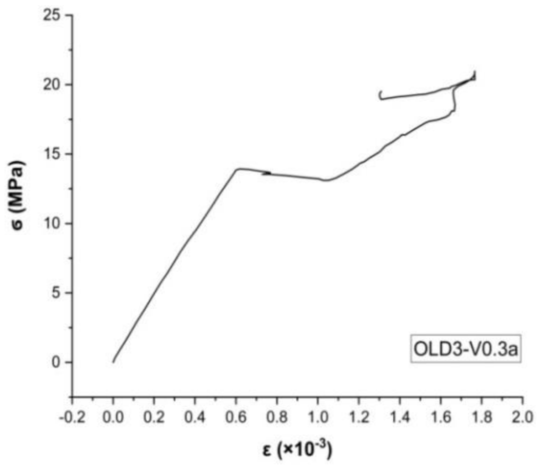

Fig. 12 - 0.3mm/min cyclic loading and unloading

Fig. 13 - OLD3 Specimen crack propagation

Fig. 14 - OLD3 Specimens failure

Figure 15 show that the maximum stress of OLD4 is 13.3MPa. When stress reaches about 5.3MPa, cracks appear on the surface of the specimen as shown in Figure 17. At the same time, there is an aggregate expansion at the clamp position of the extensometer. The specimen continues to withstand pressure but strain change is irregular. The maximum stress of OLD5 is 18.5MPa. At the beginning of loading, the stress-strain curve of OLD5 increases linearly and the slope of the straight line is 3.3x10^{4}. When stress reaches 10MPa, strain suddenly decreases from 0.3x10^{-3} to 0.5x10^{4}, and stress-strain curve shows irregular changes as shown in Figure 16.

The reason for rapid decrease of strain in the test process is that when stress reaches 10MPa, the specimen produces large cracks at the measuring point of the extensometer (as shown in the Figure 18), at the same time, the aggregate particle expands at the measuring point, which results in the reverse slip of measuring for the extensometer. Stress continues to grow when the pressure continues but the strain changes irregularly. Finally, when the stress reaches 18.5MPa, the specimens are destroyed.

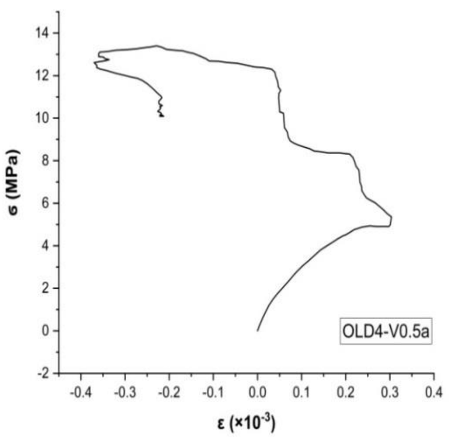

Fig. 15 - 0.5mm/min cyclic loading and unloading

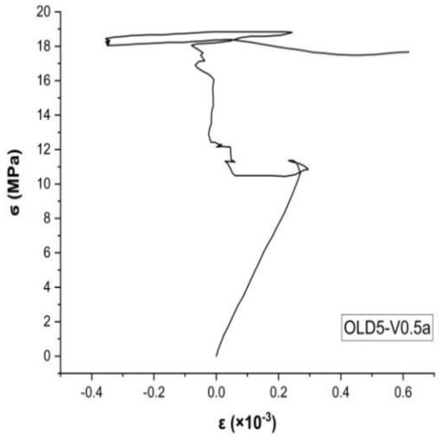

Fig. 16 - 0.5mm/min cyclic loading and unloading

Fig. 17 - OLD4 Specimen cracks propagation

Fig. 18 - OLD5 Specimens cracks propagation

Tab. 10 - Data analysis table for old specimens loaded at one time

Loading speed (mm/min)	0.1	0.3		0.5		Average value
Specimen number	OLD1	OLD2	OLD3	OLD4	OLD5	
Fracture propagation (MPa)	9	4.8	14	5.3	10	8.6
Maximum stress (MPa)	12.9	8.6	21.1	13.3	18.5	14.8

Data analysis for old concrete specimens loaded at one time is shown in Table 10. It can be seen that the maximum stress of the old cement concrete specimens in one-time loading test is 14.8MPa and the crack propagation began when the average stress of the specimens reached 8.6MPa. The stress-strain curve and experimental phenomena show that the cracks appeared early in the loading process of the old cement concrete specimens. The failure of the specimens was brittle and the whole structure showed as a loose state after failure.

Cyclic Loading and Unloading Test

The cyclic loading and unloading of new concrete specimens were carried out at loading rates of 0.1mm/min, 0.3mm/min and 0.5mm/min and the range of cyclic loading force was 0.05-150KN respectively. The stress-strain relationship for cyclic loading and unloading tests for new concrete specimens is shown in Figs. 19-23.

The stress-strain curves of cyclic loading and unloading of new cement concrete specimens is a closed loop with repeated cycles when the loading speed is 0.1mm/min. The cycle curve is slightly upward when the loading speed is increased to 0.3mm/min and the stress-strain curve is approximately a straight line at 0.5mm/min loading speed. Table 11 lists the elastic modulus values E_c of the five curve cycle stages and the magnitude of the sum value at the sixth load failure.

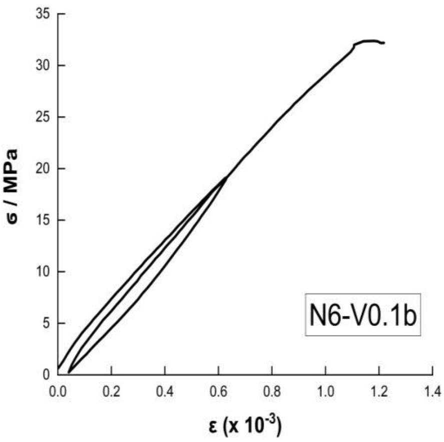

Fig. 19 - 0.1mm/min cyclic loading and unloading

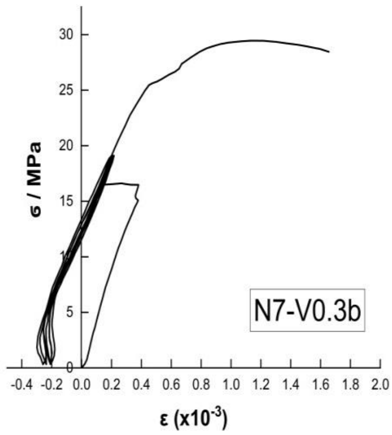

Fig. 20 - 0.3mm/min cyclic loading and unloading

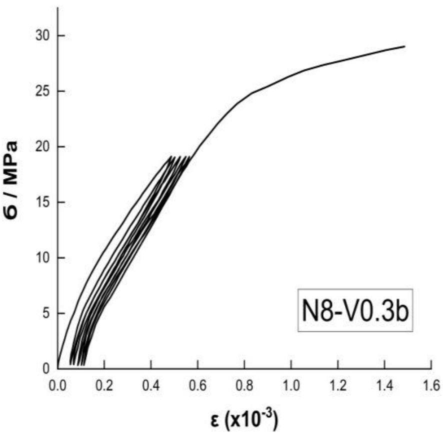

Fig. 21 - 0.3mm/min cyclic loading and unloading

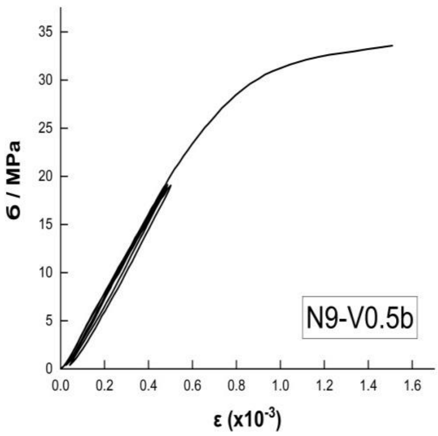

Fig. 22 - 0.5mm/min cyclic loading and unloading

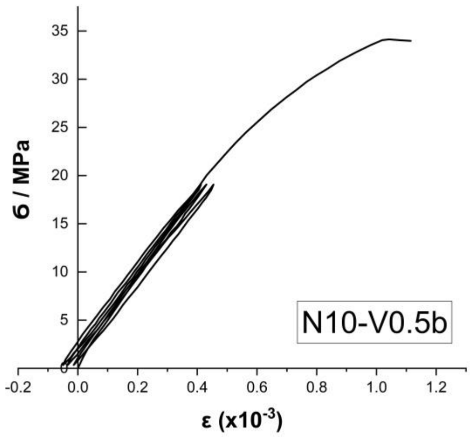

Fig. 23 - 0.5mm/min cyclic loading and unloading

Tab. 11 - Data analysis table for cyclic loading and unloading of new specimens

Loading speed (mm/min)	0.1	0.3		0.5		Average value
Specimen number	N6	N7	N8	N9	N10	
[odulus of elasticity in cyclic stage E_c (×10^4MPa)	3.16	3.42	3.38	4.06	3.91	3.58
Maximum stress (MPa)	33.1	29.5	29.2	33.5	34.1	31.9
Maximum strain (×10^{-3})	1.18	1.16	1.48	1.52	1.15	1.3

Through the data analysis table, it can be seen that the elastic modulus E_c measured in the cyclic loading and unloading stage of new cement concrete specimens increases with the increase in loading speed. The average maximum stress of the new cement concrete is 31.9 MPa with a maximum stress and strain of 34.4MPa and 1.30×10^{-3} which is less than the maximum strain of the one-time loading failure. Whereas, the cyclic loading and unloading test overall decreased the overall compressive and deformation resistance of the new concrete specimens.

The cyclic loading and unloading of old concrete specimens were carried out at loading rates of 0.1mm/min, 0.3mm/min and 0.5mm/min and the range of cyclic loading force was 0.05-100KN respectively. The stress-strain relationship for cyclic loading and unloading tests for new concrete specimens is shown in Figs 24-28.

From the stress-strain curve analysis and experimental phenomena description of five old specimens during cyclic loading and unloading test in Figs 24-28, it can be seen that the test results of old cement concrete specimens are very discrete which indicates that there are different degrees of structural damage inside the specimens. Specimen OLD6 & OLD8 had cracks at the first loading; OLD9 specimens had cracks during loading and unloading cycles; OLD7 successfully completed the loading and unloading tests without cracks. The elastic modulus Ec of cyclic stage is 2.6×10^4MPa, and the linear elastic modulus E_c of OLD9 and OLD10 at the initial loading stage is 2.1×10^4MPa respectively. The average elastic modulus E_c of the three specimens is 2.6x104 MPa, which is less than the average E_c of cyclic loading and unloading of new cement concrete 3.58×10^4MPa.

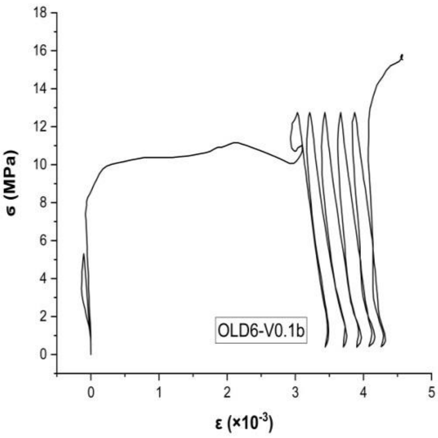

Fig. 24 0.1mm/min cyclic loading and unloading

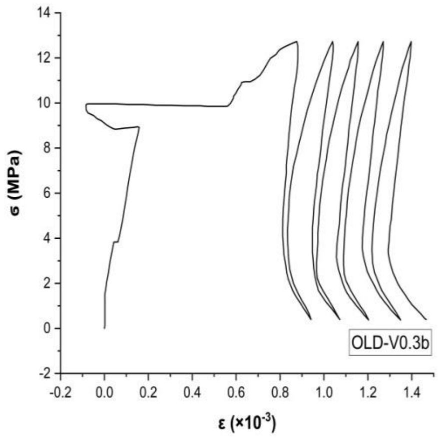

Fig. 26 0.3mm/min cyclic loading and unloading

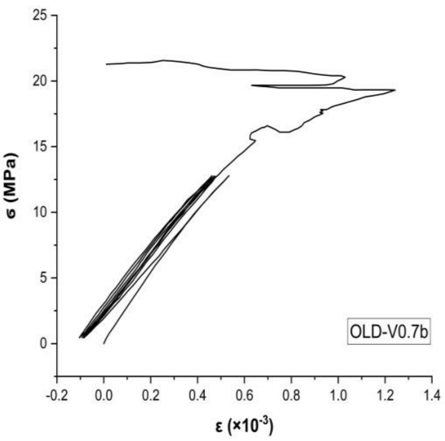

Fig. 25 - 0.3mm/min cyclic loading and unloading

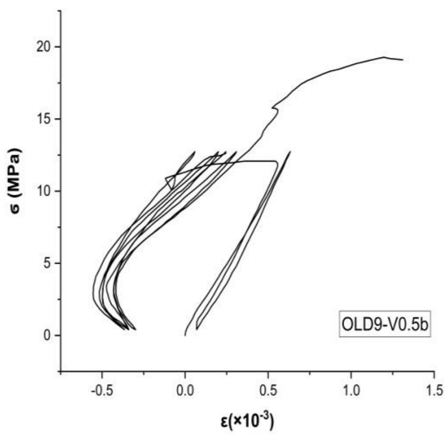

Fig. 27 - 0.5mm/min cyclic loading and unloading

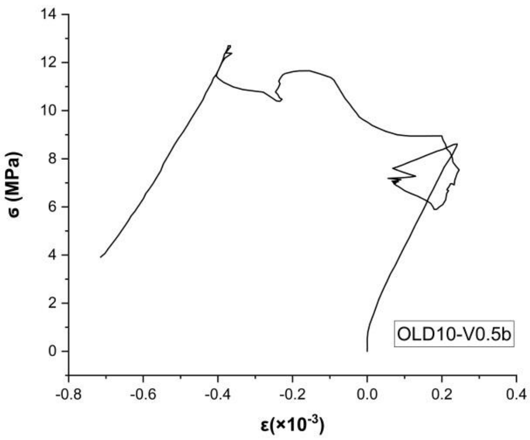

Fig. 28 - 0.5mm/min cyclic loading and unloading

Table 12 illustrates the data comparison for rheological analysis of new and old cement concrete specimens when cyclic loading and unloading is applied at different loading speeds. When the loading speed is small, E_c tends to decline as a whole and stress-strain curve is slightly raised upward; when the loading speed is large, E_c maintains a horizontal straight line in a certain range and stress-strain curve basically propagates in a straight line. This shows that the rheological behavior of cement concrete specimens will be affected by different loading speeds in a certain stress and strain range. When the loading speed is larger, the stress-strain curve of the specimens basically shows linear elastic property. When the loading speed is smaller, the stress-strain curve of the specimens will change viscoplastically.

Tab. 12 - Overall data comparison for new and old concrete specimens

Specimen Type	Average maximum stress (MPa)	Maximum stress change range (MPa)	Average modulus of elasticity E_c (×10^4 MPa)	Change range of elastic modulus E_c (×10^4 MPa)
New Cement Concrete specimens	33.7	30.6-36.8	3.37	3.16-4.06
Old Cement Concrete specimens	14.8	8.6-21.1	2.6	2.1-3.1

CONCLUSIONS

The experimental study on rheological behaviour of old and new concrete by combining the test phenomena and the damage degree of the specimens gives the following conclusions:

Stress-strain curves of new cement concrete specimens increases approximately linearly in a certain range ($\sigma \leq 80\%\sigma_{max}$), which is in the elastic working stage of cement concrete. Different loading speed will affect secant modulus E_s and maximum stress of stress-strain curves. E_s increases with the increase in loading speed and the maximum stress increases slightly with the increase of loading speed which indicates that cement concrete has certain viscous properties. When ($\sigma \leq 80\%\sigma_{max}$) is applied, the concrete specimens deform with great extent and destroy quickly.

The cyclic loading and unloading test results of new cement concrete specimens show that the cyclic loading and unloading of new cement concrete specimens at different loading speeds is within the pressure range of 0.05-150KN. The stress-strain curve can basically return in accordance with the original path where all of them have different degrees of migration which is caused by the mechanical properties of the material itself. At different loading speeds the stress-strain curves basically return in accordance with the original path and have different degrees of viscous deformation. When the loading speed is small, stress-strain curves will appear as a closed loop and the closed loop will disappear with higher loading speeds which indicate small viscous deformation at low loading speeds. Therefore, the cement concrete specimens can be considered in the stage of elasticity.

The average damage stress of old cement concrete specimens is far less than that of new cement concrete specimens and cracks appeared early in the loading process of old cement concrete specimens at one-time loading process. The damage of specimens is a brittle fracture failure and the whole structure represented as a loose state after failure.

From the stress-strain curve analysis of the old cement concrete specimens under cyclic loading and unloading test, it can be concluded that the stress-strain curve of some old specimens with relatively complete structure almost increases in line at the initial stage of loading. The measured elastic modulus E_c value is much smaller than that of the new cement concrete specimens and the overall compressive and deformation resistance ability decreased significantly.

The old cement concrete specimens are drilled on the cement pavement which has been used for 6 years. The internal structure of the specimens is damaged to varying degrees, so the test results are quite discrete. The surface of some specimens had cracked and the cracks begin to expand at the initial stage of loading. The expansion of the cracks may have caused the extensometer to move up and down, so the stress-strain curves of some old cement concrete specimens show hopping movement from left to right.

When ($\sigma \leq 80\% \sigma_{max}$), the cement concrete material mainly show elastic change law and also have a small amount of viscous deformation; stress-strain curve can basically return in accordance with the original path in the cyclic loading and unloading test and the cement concrete specimens are in the linear elastic stage. It can be concluded that the theoretical assumption of elastic foundation slab system of cement concrete pavement is valid and the elastic analysis and calculation of concrete buildings are also scientific.

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