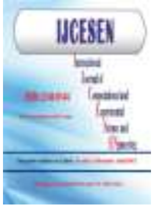
International Journal of Computational and Experimental Science and ENgineering
(IJCESEN)

Vol. 10-No.3 (2024) pp. 292-298
http://www.ijcesen.com
Research Article



ISSN: 2149-9144

Creep Coefficient for Self-Compacting Concrete (SCC)

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Article Info:

DOI: 10.22399/ijcesen.363
Received : 29 June 2024
Accepted : 23 July 2024

Keywords:

self-compacting concrete
modulus of elasticity
compressive strength
shrinkage
creep

Abstract:

With the development of construction technology, self-compacting concrete has started to be widely used in the construction of buildings. The specific properties of self compacting concrete have made it particularly useful for concreting the structural elements of high-rise buildings. The strains characteristics of concrete are important to know both in the initial stage of concreting and in the long process, in order to take measures to minimize their impact on cracking and reduction of structure elements. In this regard we have conducted an experiment to investigate shrinkage strains and creep strains in reinforced concrete beams as well as the determination of the creep coefficient. Given that the shrinkage and creep strains are together, it is necessary to separate the creep strains from the shrinkage strains to determine the creep coefficient. For the realization of this separation, we have prepared the same samples which have been used for the determination of shrinkage strains and samples which have been inserted into the mechanisms for the realization of adequate force for the determination of the creep strains.

1. Introduction

Concrete strains in the long-term process, such as shrinkage strains and creep strains, make changes in the stresses of reinforced concrete structures. In some types of concrete structures, for example bridges and tall structures, the stresses and strains that are function of time can be several times larger than the strains at the moment of loading. Many concrete models have been developed over time to describe the time-dependent behavior of concrete structures, which have adapted the constituent components of concrete (cement, admixtures, and aggregate) to changing concrete mix design. The literature and codes are sometimes too simplistic, leading to misunderstandings in the real-time behavior of concrete structures [1, 2, 3, 4, 5].

Shrinkage is a reduction in the volume of unloaded concrete that begins during its hardening and continues until its final hardening. Eurocode 2 [EN-1992] mainly deals with two types of shrinkage strains according to their origin:

a) Endogenous shrinkage (or early shrinkage) of chemical origin, which starts very early and ends quite quickly after a few days and which is due to a reduction in the volume of the cement paste during its hydration;

b) Exogenous shrinkage, due to a change in internal hygrometry, which does not start practically until the removal of the formworks and is a slow and long-term process [6].

Creep in concrete is the phenomenon whereby the strain of concrete subjected to a constant load continues to increase with time. Creep also depends on the factors cited above, the safety of the concrete at the time of loading and the duration and intensity of the applied load [6]. The simplified linear creep hypothesis is normally acceptable provided it limits compressive strength in concrete to 0.45fck (or 0.45fck (t0)) [6]. The magnitude of the creep coefficient varies depending on the humidity, the quality of the concrete, the duration of the applied load and the age of the concrete when loading, the creep coefficient = (creep /elastic strain) Eq.(3) [6]. The age-adjusted effective modulus method (AAEM) [1, 3] is one of the methods for the analysis of creep strains of composite structures. This is a practical method to directly calculate strain in the long-term process, developed by Trost in 1967 and later improved by Bazant. A concept of aging coefficient is introduced in this creep analysis method [7]. The main factors that affect the shrinkage and creep of concrete are as follows:

a) Ambient humidity, shrinkage and creep will decrease with increasing ambient humidity, and relative humidity has a greater impact on early creep.
b) Aggregate grain size, with the use of large aggregate grain the strains from shrinkage and creep are reduced.
c) The age of the concrete at the moment of loading, the shear and other conditions are unchanged, the solidity of the concrete develops faster and the creep becomes smaller.
d) Type of cement, in general, the heat of hydration of cement causes strains from shrinkage and in this case cracks in the concrete surface, but expansive cement can reduce shrinkage in concrete to a great extent. Cement also affects creep by affecting the strength of concrete [8,9,10,11].
e) The level of load applied during creep coefficient testing has a very important role during each time interval. As the load increases, the creep coefficient will also increase, as seen in Figure 1 [12]. In this paper will be presented the results for the mechanical characteristics of self-compacted and normal concrete such as: Solidity in compression, modulus of elasticity, tensile splitting strength. The results for shrinkage and creep strains and the results for the creep coefficient for normal concrete and for self-compacted concrete will also be presented.

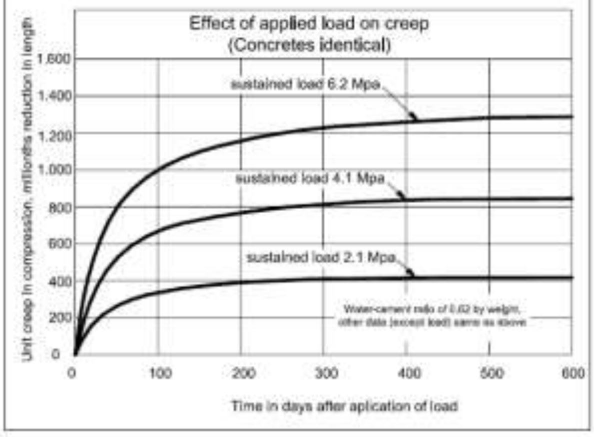

Figure 1. *Influence of the level of compressive solidity on the creep coefficient*

2. Methodology

For the production of concrete, the aggregate obtained from the limestone rocks is used, three fractions of the aggregate are used: Fraction I 0/4; Fraction II 4/8; Fraction III 8/16, for self-compacted concrete, stone powder is used, which is produced from the same stone as the aggregate, drinking water, Portland cement PC 42.5N, as well as the hyper-plasticizer additive are used.
The quantitative content of the constituent materials of the concrete mixtures for normal concrete and self-compacting concrete (SCC) are presented in Table 1.

Table 1. *Mix design of normal and self-compacting concrete*

	Normal Concrete [kg/m^3]	**SCC [kg/m^3]**
I 0/4	708	750
II 4/8	435	468
III 8/16	714	485
S. pow	X	98
PC 42.5N	325	315
W	215	195
Admixture hyper plasticizer	X	3.5

2.1 Compressive Strength of Concrete EN1930-3

For compressive strength testing, 12 cubic samples with dimensions of (150x150x150) mm were prepared, where 6 samples were from normally concrete (NC) and 6 others from self-compacting concrete (SCC). The testing was carried out in the hydraulic press with a force action speed of 600 kPa/s and a sensitivity of 6 kN. The samples were tested at the age of concrete t=28 days and t=360days. Laboratory testing process and preferred form of fracture of cubic specimens according to EN 1930-3 is shown in Figure 2 [13, 14, 15, 16, 17, 18].

Figure 2. *Process of testing the compressive strength of concrete*

2.2 Modulus of Elasticity of Concrete ASTM 469

Cylindrical samples with dimensions of (150x300) mm were used to determine the modulus of elasticity. Before testing the modulus of elasticity, the cylindrical samples were tested for compressive strength to determine fck, which was used to determine the load level of the samples to determine the modulus of elasticity (0.4 fck). The testing was carried out in the automatic hydraulic press with a speed of force action (240 ± 30) kPa/s using cyclic loading in three cycles of loading and unloading with a stress level of 0.4 fck by measuring the strains on three sides. After three almost identical results, the strain and then the modulus of elasticity were determined. The process of testing the modulus of elasticity in the laboratory as well as the method of determining the Poisson's ratio according to the ASTM 469 standard is shown in Figure 3 [12, 16, 19, 20, 21, 22].

Figure 3. *Process of testing the modulus of elasticity*

2.3 Splitting Tensile Strength of Concrete EN 1930-6

Testing of splitting tensile strength was determined on cubic samples (150x150x150) mm, the speed of the load action in the press was 60 kPa/s (according to EN1930-6 it is 0.04-0.06 MPa/s) and with sensitivity 0.6 kN. Six samples were tested, three from normally concrete and three from self-compacting concrete. Testing press and method for determining splitting tensile strength according to the standard EN1930-6 is shown in Figure 4 [15, 16, 17]. The apparent tensile strength measured depends upon the shape and size of the test specimen used, cubes gave higher measured tensile strengths than cylinders, by approximately 10 % and 150 mm cubes gave lower measured tensile strengths than 100 mm cubes [15].

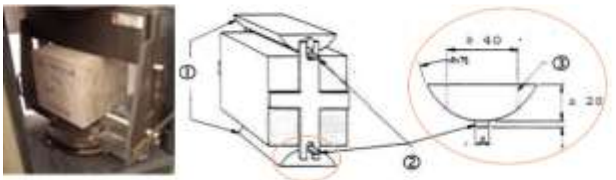

Figure 4. *Process of testing the compressive strenght of concrete: (1) Steel loading piece (2) Hardboard packing (3) Segment may be trimmed*

2.4 Shrinkage Strains

In order to determine these strains, prismatic samples with dimensions of (10x10x40) cm have been prepared, where on each side of the prisms there are benchmarks for measuring strains from shrinkage. The samples are placed in the same environment as the samples for the determination of creep strains. The temperature of the environment was *T*=20±20C while the relative humidity of the environment RH=65±5%. The measurement of the strains started from the moment the samples were removed from the formwork. The samples were placed on the support cylindrical from the plastic mass in order not to prevent their deformation throughout the time of research Figure 5.

2.5 Creep Strains

To investigate these strains, the same samples as those for the investigation of shrinkage strains were prepared, prismatic samples with dimensions of (10x10x40) cm. At the age of the concrete *t*=28 days, the samples were placed in the mechanism where after the realization of the load, which was constant until the end of the research (t=380 days). At the moment of loading the samples, the elastic strains ε_e were measured. In the following days, the total strains were measured.

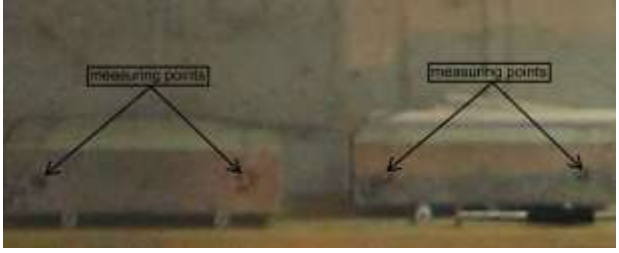

Figure 5. *Experimental investigation of shrinkage strains in prismatic samples*

Total strains:

$$\varepsilon_{tot}(t, t_0) = \varepsilon_e + \varepsilon_c(t, t_0) + \varepsilon_s(t, t_0) \qquad (1)$$

$\varepsilon_{tot}(t, t_0)$ - total strain
ε_e - elastic strain
$\varepsilon_c(t, t_0)$ - creep strain
$\varepsilon_s(t, t_0)$ - shrinkage strain

Creep strains are obtained with the expression:

$$\varepsilon_c (t, t_0) = \varepsilon_{tot} (t, t_0) - \varepsilon_e - \varepsilon s (t, t_0) \qquad (2)$$

εc (t, t0) - creep strain
εtot (t, t0) - total strain
εe - elastic strain

2.6 Creep Coefficient

To determine the coefficient of creep, it is necessary to prepare the same samples for examination in the long-term process of shrinkage strains and total strains (creep strains and shrinkage strains together). The samples for both cases must be treated under the same hydrometric and thermal conditions.

The creep coefficient represents the ratio between creep strains and elastic strains (deformation at the moment of loading) expression (3):

$$\varphi (t, t_0) = \varepsilon_c (t, t_0) / \varepsilon_e \qquad (3)$$

φ (t, t0) - creep coefficient
ε c (t, t0) - creep strain
ε e - elastic strain

It is therefore necessary to separate creep strains from shrinkage strains. This is done in such a way that parallel to the samples placed in the mechanism where elastic strains, creep strains and shrinkage strains are measured together Eq.(1) in separate samples we must measure the strains from shrinkage. By subtracting the elastic strains and shrinkage strains from the strains measured in the mechanism (ε tot (t)), we only have creep strains at any time interval, which are then divided by
the elastic strains. In this way we obtain the results of the creep coefficient in any time interval [9].

2.7 Determination of Creep Coefficien Experimentally – Equipment for Determining the Creep Coefficient

For the investigation of the creep coefficient, a closed steel ram construction was developed. In its lower part, between the two plates, there are four high-quality steel springs. In the upper part of the frame, the position where the piston is placed to realize the force is foreseen, and then the plates are tightened through the screws, which are pressed by the force exerted by the springs.

This device also consists of 4 metal rods Φ 30 mm and a metal plate is placed in the middle of the frame in order to avoid bending between the two prisms.

In order to exert force in the centre of the cross-section of the prisms, moving metal heads have been made. The schematic presentation and photo of this mechanism is presented in Figure 6. A mechanical extensometer with a digital reader was used to measure the placements in the prisms. The reader has an accuracy of 0.001 mm while the step of the extensometer is *l*=300 mm. The mechanical extensometer is presented in Figure 7.

3. Results

The results of laboratory testing for the mechanical characteristics of normal concrete and selfcompacting concrete are presented as follows: The concrete compressive strength results are presented in Table 2, the modulus of elasticity

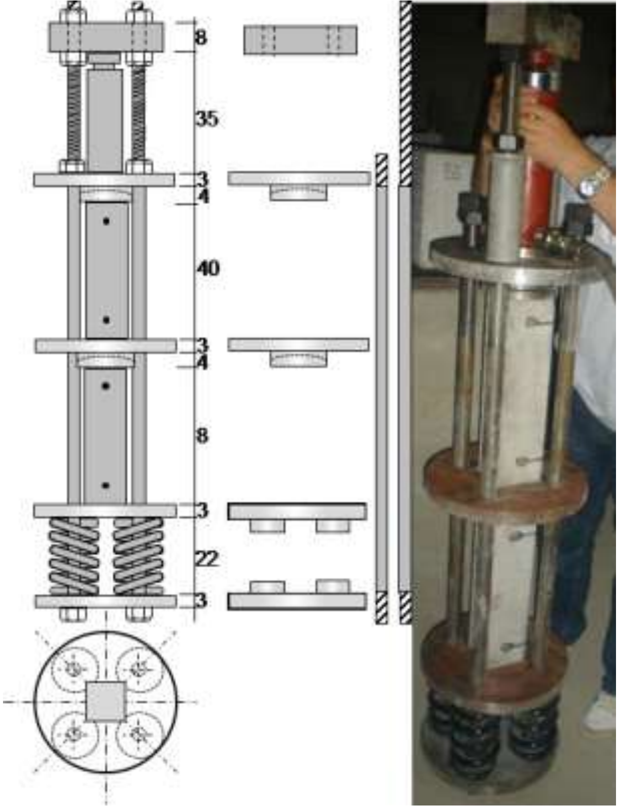

Figure 6. *Schematic representation and photo of creep coefficient setting mechanism*

Figure 7. *Mechanical exensometer with digital reader*

results are presented in Table 3. In the Table 4 shows the experimental results of shrinkage, while in Figure 8, the results are shown in graphic form. The splitting tensile strength results are presented in Table 5.

Table 3. *Results of laboratory testing of moduls of elasticity*

E [N/mm^2]	**Em [N/mm^2]**	**E [N/mm^2]**	**Em [N/mm^2]**
NC t=28days		SCC t=28days	
33584		33285	
33345		32374	
32784	33238	33296	32985
NC t=360days		SCC t=360days	
37066		34093	
35949		35536	
34030	35682	35080	34903

Table 4. *Experimental results of shrinkage [%]*

t [days]	**Ɛ s [N]**	**Ɛ s [SCC]**
20	0.000	0.000
50	0.111	0.107
100	0.138	0.151
150	0.145	0.170
200	0.148	0.199
250	0.166	0.224
300	0.174	0.236
350	0.189	0.251
380	0.198	0.254

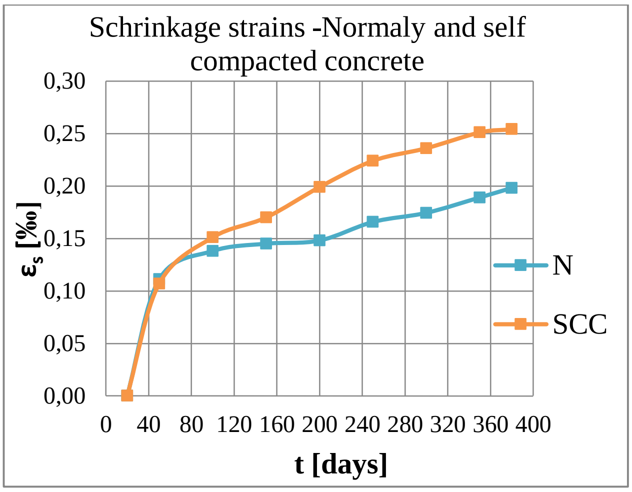

Figure 8. *Experimental shrinkage results in graphical form*

Experimental results for shrinkage and creep strains are presented in Figure 9. For normal concrete and in Figure 10, for self-compacted concrete.

Table 5. *Results of laboratory testing of modulus of elasticity*

Normal Concrete									
Nr.	Sign	Ade [day]	Dimensions [mm]	Mass [gr]	Density [kg/m^3]	Area [mm^2]	Force [kN]	T.S.S fct [N/mm^2]	T.S.S.m
1	M-1 NC	28	150	8102	2401	22500	156.30	4.41	
2	M-2 NC	28	150	8030	2379	22500	161.40	4.56	
3	M-3 NC	28	150	8110	2403	22500	148.70	4.20	4.39
Self Compacting Concrete									
Nr.	Sign	Ade [day]	Dimensions [mm]	Mass [gr]	Density [kg/m^3]	Area [mm^2]	Force [kN]	T.S.S fct [N/mm^2]	T.S.S.m
1	M-1 SCC	28	150	7761	2300	22500	153.60	4.33	
2	M-2 SCC	28	150	7832	2321	22500	144.30	4.07	
3	M-3 SCC	28	150	7815	2316	22500	150.20	4.24	4.22

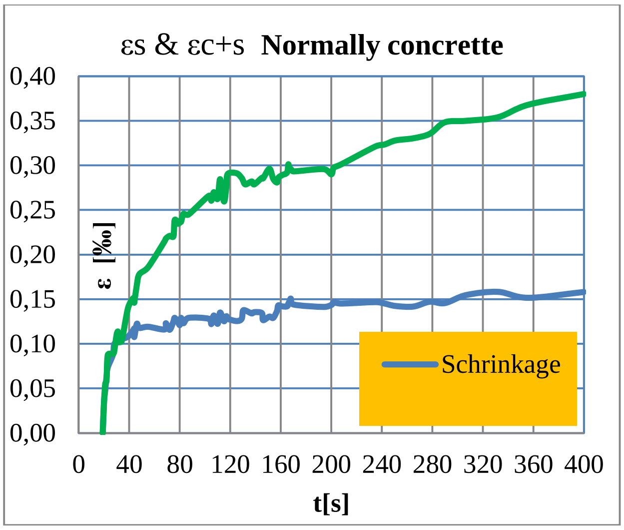

Figure 9. *Experimental results of shrinkage and creep strains in grahpical form for noraml concrete*

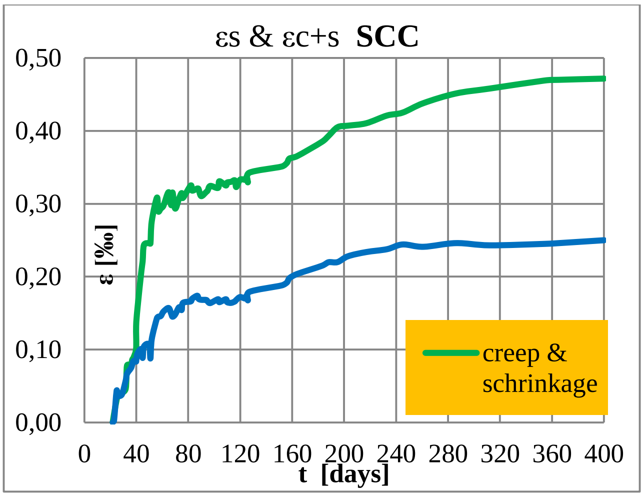

Figure 10. *Experimental results of shrinkage and creep strains in grahpical form for self-compacting concrete*

During the experiment to determine the creep coefficient, a force was realized, which was constant during the period from t=28 days to the period t=380 days. During this time interval, the force level in the mechanism was checked from time to time [9].

The experimental results are presented in Table 6. While the experimental results in graphic form are presented in Figure 11.

Table 6. *Experimental results of creep coefficient*

φ (t, t0)		
Days	**N**	**SCC**
28	0.000	0.000
40	0.094	0.115
60	0.187	0.267
100	0.264	0.323
150	0.270	0.357
200	0.280	0.388
250	0.339	0.445
300	0.399	0.500
350	0.477	0.567
380	0.531	0.610

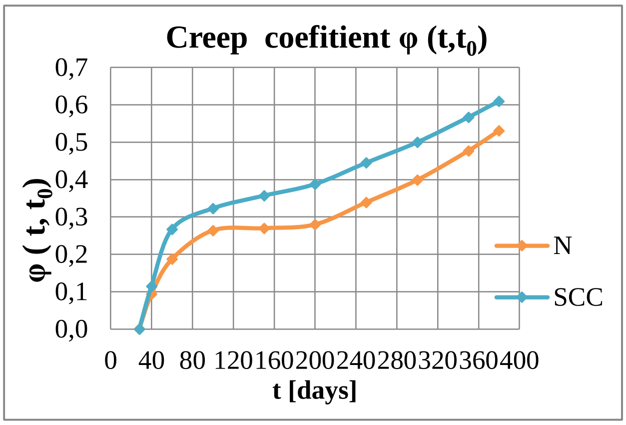

Figure 11. *Experimental results of creep coefficient graphically*

4. Conclusions

The modulus of elasticity of samples from self-compacted concrete both for time t=28 days and also for time t=380 days has smaller values compared to the modulus of elasticity of ordinary concrete, this happens because self-compacted concrete in its composition contains more aggregate grains.

After comparing the results of laboratory testing of tensile splitting strength of samples from normally concrete and samples from self-compacted concrete, we conclude that samples made from self-compacted concrete have lower tensile strength than samples made from normally concrete.

During the investigation of prismatic samples in shrinkage and creep, it was observed that samples from self-compacted concrete have greater values of shrinkage and creep results compared to samples from normally concrete.

Throughout the time of the research, it is observed that the creep coefficient is greater in selfcompacted concrete samples.

With the application of the load with a solidity of less than 0.4 fck, smaller values of the drag coefficient are obtained. In the specific case, the compression solidity of 4.5 MPa was applied, therefore the values of the creep coefficient after one year are φ (360, 28)=0.531 for normally concrete or φ (360, 28)=0.610 for self-compacting concrete.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] Bažant, Z. P., Li, G. H., and Yu, Q. (2009). Prediction of Creep and Shrinkage and Their Effects in Concrete Structures: Critical Appraisal *In Proceedings of Eighth International Conference on Creep, Shrinkage and Durability Mechanics of Concrete and Concrete Structures*, 2, 1275-1289. https://www.scholars.northwestern.edu/en/publications/prediction-of-creep-and-shrinkage-and-their-effects-in-concrete-s

[2] Nicola S, Roberto S, Matteo M, Daniele M, Rui P, Gian Michele C. Collapse analysis of the multi-span reinforced concrete arch bridge of Caprigliola, Italy. *Engineering Structures*, 251(A), 113375. https://doi.org/10.1016/j.engstruct.2021.113375

[3] Ahmed K, Galal F, Abdulrahman S. A. Assessment of concrete shear resistance of lightweight SCC beams containing scoria aggregates.

Journal of Building Engineering, 78, 107591. https://doi.org/10.1016/j.jobe.2023.107591

[4] Yun Guo Zhang, Zhi Min Wu, Xi Wu. Experimenta Investigation on the Shrinkage and Creep Performance of SelfCompacting Lightweight Concrete.
Advanced Materials Research, 860-863, 1349-1353.
https://doi.org/10.4028/www.scientific.net/AMR.860-863.1346

[5] Xian Yu Jin, Chuan Qing Fu, Nan Guo Jin, Fan Ge, Yi Bing Zhao. Shrinkage Cracking Resistance Property of SelfCompacting Concrete.
Advanced Materials Research, 250-253, 383-387.
https://doi.org/10.4028/www.scientific.net/AMR.250-253.383

[6] EN 1992-1-1 (2004) (English): Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings.
The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC
https://www.phd.eng.br/wp-content/uploads/2015/12/en.1992.1.1.2004.pdf

[7] Shrestha K M, CHEN Baochun. Aging Coefficient, Creep Coefficient and Extrapolating Aging Coefficient from Short Term Test for Sealed Concrete.
Journal of Wuhan University of Technology, 26, 154-159
https://doi.org/10.1007/s11595-011-0188-2

[8] JTGD-62 2004 Code for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts [S].
Issued by Ministry of Transport of the Pople's Republic of China, JTG D62-2004
https://www.codeofchina.com/standard/JTGD62-2004.html

[9] CEB-FIP Model Code 1990 [S]. Thomas Telford Services Ltd, Thomas Telford House, 1990.
Thomas Telford Services Ltd, Thomas Telford House, 1 Heron Quay, London E14 4JD.ISBN:0 7277 1696 4
https://wwwtocasa.es/zona2/CEB_FIP_model_code_1990_ing.pdf

[10] Young San Cheng, Ke Qiang Yu, Shuang Xi Wang. Research on Mixture Ratio of Recycled Concrete Aggregate in Concrete.
Applied Mechanics and Materials, 193-194, 1371-1375.
https://doi.org/10.4028/www.scientific.net/AMM.193-194.1371

[11] Hong Yan Liu, Jin Gang Qi. The Effect of Mixture Parameter on the Properties of SCC.
Advanced Materials Research, 299-300, 355-358.
https://doi.org/10.4028/www.scientific.net/AMR.299-300.355

[12] Joseph A. Dobrowolski, McGraw-Hill Handbooks CONCRETE CONSTRUCTION ENGINEERING Handbook.
McGraw-Hill, Subsquent, ISBN-13:978-0070171985.

[13]BS EN12390-5:2009 Part 5: Flexural strength of test Specimens.
British Standard, BS EN 12390-5:2009 Part 5.
https://kupdf.net/download/bs-en-12390-5-2009-part-5-flexural-strength-of-testspecimens_58caa120dc0d60ab1033902f_pdf

[14] BS EN 12390-3-2002 Part 3: Compressive strength of test specimens.
British Standard, BS EN 12390-3:2002 Part 3.
https://pdfcoffee.com/bs-en-12390-3-5-pdf-free.html

[15]BS EN 12390-6:2000 Part 6: Tensile splitting strength of test specimens.
British Standard, BS EN 12390-6:2000 Part 6.
https://pdfcoffee.com/bs-en-12390-6-2009-testing-hardened-concrete-part-6-tensile-splittingstrength-of-test-specimens-pdf-free.html

[16] Domone P.L. A review of the hardened mechanical properties of self-compacting concrete.
Cement and Concrete Composites, 29(1), 1-12.
https://doi.org/10.1016/j.cemconcomp.2006.07.010

[17] Muhammed F. Hama, Mohammed P. Anwar, Lau T. Leong, Daryl Ng Chun Pinn. Influence of Superplasticizer Dosage on the Workability and Compressive Strength of Tenera Oil Palm Shell Concrete.
Journal of Advanced Research in Applied Sciences and Engineering Technology, 31(1), 383-394.
https://doi.org/10.37934/araset.31.1.383394

[18] Amminudin Ab Latif, Ramadhansyah Putrajaya, Doh Shu Ing. A Review of Porous Concrete Pavement: Compressive Strenght and Cloggin Investigagion.
Journal of Advanced Research in Applied Sciences and Engineering Technology, 29(3), 128-138.
https://doi.org/10.37934/araset.29.3.128138

[19] Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression.
ASTM International, United Stades, PO Box C700.
https://pdfcoffee.com/norma-astm-c-469pdf-pdf-free.html

[20] Wenzhong Zhu, Peter J.M Bartos. Permeation properties of self-compacting concrete.
Cement and Concrete Composites, 33(6), 921-926.
https://doi.org/10.1016/S0008-8846(02)01090-6

[21] Wei Jiang, Youjun Xie, Kunlin Ma, Junging Wu, Guengcheng Long. Research on two-dimensional digital characterization of crushed stone aggregates in the SCC filling layer of the CRTS III slab ballastless track.
Construction and Building Materials, 403(3), 133132.
https://doi.org/10.1016/j.conbuildmat.2023.133132

[22] Danijela Zejak. Approximate Methods for Analysing the Effects of Creeping and Shrinkage of reinforced and Prestressed Concrete Constructions.
Procedia Engineering, 117, 712-722.
https://doi.org/10.1016/j.proeng.2015.08.199