Use of Weight Maturity Method for Building Concretes Used in Artvin Yusufeli Dam Construction

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Abstract

The aim of this study is to compare the compressive strength determined by weight maturity method in dam concretes with compressive strength obtained from fresh concrete and core samples. Within the scope of the study, normal concretes of C25/30 strength class were produced. Samples were taken from $\phi 15 \times 30$ cm cylinder molds from normal concrete mixtures having maximum aggregate grain diameter (D_{max}) of 25 mm. In this study, the estimated compressive strengths were measured by using a maturity device and the compressive strengths obtained from samples taken from fresh concrete and core samples taken from hardened concrete were measured at close values. In this context, instead of taking samples from fresh concrete and concrete productions, it was concluded that the pressure resistance measurements made by using a maturity device in fresh concrete are reliable.

1. Introduction

In order to determine the safety of a concrete structure, it is evaluated by carrying out sufficient and in situ measurements of the carriers forming the concrete structure. The most important consideration when designing this concrete is compressive strength [1]. It is known that in many researches on concrete, concrete compressive strength changes in parallel direction with other properties such as tensile strength, flexural strength, and shear strength. Therefore, the quality of concrete is generally evaluated by compressive strength. It is primarily desirable to provide the strength class in the structure so that the concrete produced is of good quality. Determination of the compressive strength class of concrete can be made from cylinder or cube samples taken in fresh concrete, core samples taken from hardened concrete or from methods recommended as non-destructive methods. Taking too many samples from concrete poured in very large volumes in construction site applications leads to curing problem, unnecessary waste of large amounts of concrete and health problems for workers [2].

Concrete compressive strength is directly affected by concrete age and temperature. This effect is particularly evident at an early age when the hydration reaction occurs rapidly. Therefore, accurate estimation of concrete properties at an early age is necessary for stress analysis in concrete structures [3]. This leads to the development of a number of theoretical and experimental approaches to predict concrete compressive strength at an early age in concrete [4]. One of the recommended methods for determining the compressive strength of concrete in situ is the weight maturity method in fresh concrete [5]. With the maturity weight method used as a non-destructive test method, the compressive strength of concrete can be estimated close to the real value [6]. In the studies, it is seen that the compressive strength of concrete from the core samples is estimated as close to reality by weight maturity method [7]. It is the most important parameter to know the strength gain speed of the concrete in order to remove the mold in the shortest time in the field conditions. Different parameters are taken into account in determining the minimum demoulding time, but concrete

temperature is always the only consideration [8]. With this study, compressive strength development of dam construction concrete productions was estimated. When the development of compressive strength of concrete is monitored with ultrasound and test hammer, the error margin is high [9]. It is suitable for determination of final compressive strength with core samples. It is difficult to monitor the compressive strength of concrete over the cores. In addition, if the reinforcement is accidentally cut off during core sampling from the concrete carrier elements, it may damage the carrier elements. In addition, it is difficult to find the early mold removal time by taking cores from the building concretes at an early age and its applicability under construction conditions. Depending on the sufficient strength of the concrete, the most suitable mold release time can be determined according to the maturity level of the concrete, which is one of the non-destructive methods [10]. Maturity in concrete is a method developed by determining the heat-time relationships, one of the combined factors effective in gaining strength of concrete. According to this concept, an empirical relationship can be established between temperature-time history and concrete strength development in order to estimate the strength during curing by monitoring on-site concrete temperatures in real time [11]. With the help of advanced technology, the device can measure strength values without damaging concrete structures, predict early mold making and monitor the strength development of concrete on the Internet.

In this study, C25/30 construction concrete design was made in the laboratory environment and the strength development of the concrete was followed with the maturity device in the poured concrete in the field and the determination of the concrete strength class was carried out under the actual field conditions of the maturity weight method. With this study, it is aimed to prevent the lifting of samples under heavy load according to occupational health and safety measures under heavy construction site conditions and to prevent excess material from concrete to be removed by methods such as maturity and weight.

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2. Material and Methodology

2.1. Concrete types used in the study, sample form, dimensions and places of use

In this study, C25/30 building concrete was designed and aggregates with maximum aggregate grain diameter of 25 mm were used. C25/30 class concrete was used in the construction concrete of Artvin - Yusufeli Dam and HEPP Construction. Fresh concrete samples were taken from the concretes designed in the laboratory during concrete pouring in the field. In the laboratory, 28 $\phi 15 \times 30$ cm cylinder samples were taken to find the C value for the weighted maturity method and 24 $\phi 15 \times 30$ cm cylinder concrete samples were taken to form the calibration curve. During the field concrete casting, a total of 120 $\phi 15 \times 30$ cm cylinder concrete samples were taken from fresh concrete for 3, 5, 7 and 28 days. Temperature sensors were installed in 10 different concrete products of the poured concrete on site and the pressure resistance estimation values were followed by the maturity device. At the same time, a total of 30 core samples were taken from the concrete productions followed by the maturity device and the compressive strengths measured from the fresh concrete, maturity device and core samples were compared.

2.2. Used materials

Chemical and physico-mechanical test results of CEM I 42.5 R type cement used in concrete in this study are given in Table 1.

Table 1. Chemical and physico-mechanical properties of cement

Chemical Properties	Value	Physical/Mechanical Properties	Value
CaO (%)	64.29	Specific surface (cm ² /gr)	3913
SiO ₂ (%)	17.3	Volume expansion (mm)	1
Al ₂ O ₃ (%)	4.23	Water/cement ratio (%)	30.4
K ₂ O (%)	0.67	Initial setting time (dk)	142
MgO (%)	3.36	Final setting time (dk)	190
Fe ₂ O ₃ (%)	2.50	Relative density (gr/cm ³)	3.12
Na ₂ O (%)	0.30	Compressive strength, 2 days (MPa)	25.9
SO ₃ (%)	3.06	Compressive strength, 28 days (MPa)	50.5
Cl (%)	0.01		

In this study, granite based crushed stone aggregate produced from quarry located in downstream part of Artvin - Yusufeli Dam and HEPP construction was used. 3 class aggregates were used in concrete production. The wear loss of aggregates is 12%, chemical resistance of frost resistance (with sodium sulphate) is 1% and other physical properties of aggregates are given in Table 2.

Table 2. Physical properties of aggregates

Aggregate Classes (mm)	Specific Gravity (kg/dm ³)	Water Absorption (%)	Materials Finer than No. 200 (%)	Fines Modulus	Methylene Blue
Coarse Aggregate (12-25)	2.85	0.4	0.4	-	-
Coarse Aggregate (5-12)	2.82	0.4	0.7	-	-
Fine Aggregate (0-5)	2.74	1.4	10.1	2.8	0.5

In this study, superheating Master Rheobuild 1000T chemical additive was used in the concretes and the technical properties of the chemical additive used are given in Table 3.

Table 3. Technical properties of chemical additives

Analysis	Master Rheobuild 1000T
Color	Brown
Specific gravity (kg/l)	1.061-1.101
PH	6-8
Alkali content (%)	≤ 10
Chloride content (%)	≤ 0.1
Dosage limit ranges (%)	1-2

2.3. Concrete Designs

The masses of materials with a volume of 1 m³ in C25/30 building concrete design are given in Table 4.

Table 4. Amount of materials used in concrete

Materials	C25/30	
Unit of	kg	%
Cement	300	100
Water	160	-
Water/Cement	0.53	-
Chemistry admixture (Plasticizer)	5.1	1.7
12-25 mm Coarse Aggregate	582.66	29
5-12 mm Coarse Aggregate	442.02	22
0-5 mm Fine Aggregate	984.50	49

Granulometry curve with maximum aggregate diameter of 25.4 mm used in construction concrete is shown in Figure 1. Since the concrete produced was used in the construction concretes of the Artvin Yusufeli dam, Dmax was chosen as 25.4 mm due to the frequent reinforcement of the building.

Figure 1. Aggregate gradation

The amount of collapse of fresh concrete was determined according to TS EN 12350-2 "Concrete - Fresh Concrete Tests - Part 2: Slump Test" standard[12]. TS EN 12350-6 "Concrete-Fresh Concrete Tests - Part 6: Density Test Taze of fresh concrete was carried out[13]. The air volume test was carried out in accordance with the principles specified in TS EN 12350-7 "Concrete - Fresh Concrete Tests - Part 7: Determination of Air Content - Pressure Methods"[14]. Fresh concrete test results of C25/30 building concrete are given in Table 5.

Table 5. Fresh concrete test results of C25/30 concrete class

Fresh Concrete Experiments	C25/30
Slump (cm)	15
Slump class	S3
Density (kg/dm ³)	2420
Air Content (%)	2.2

2.4. Procedures for Determination of Compressive Strength of Concrete by Weighted Maturity Method

In the weighted maturity method, the C value in Correlation 1 is calculated as the first procedure. In this study, $\phi 15 \times 30$ cm cylinder samples were taken from concretes to obtain C value in laboratory environment [16].

Concrete samples placed in cylinder molds were wrapped in stretch films without waiting for setting (Figure 2. (a), (b)). 14 of the cylinder concrete samples were stored at 20 ° C and the other 14 were stored in two different curing pools at 65 ° C (Figure 2. (c)). Temperature sensor cable was connected to 2 samples for each curing pool and connected to the maturity computer and the temperature values of both curing pools were monitored on the internet via the maturity device.

Figure 2. (a) Cylinder samples with temperature sensor cable placed, (b) Stretch wrapping of sample after temperature sensor cable was placed, (c) Placement of samples taken from fresh concrete into curing pool

Samples that were not placed at 20 °C and 65 °C without temperature sensor cable were removed from the curing pool at certain times and their compressive strength was measured by breaking the press. C value was calculated from Correlation 1 with concrete age, temperature and strength.

$$Rg = 10^{\frac{C^{0,17-1,245} - C^{-2,245}}{\ln C}}$$

In relation (1); Rg indicates the weighted maturity (in °C - hour), T indicates average concrete temperature (in °C), C in the hour, C indicates the activity value of the binder material used in the 1 hour period.

Maturity values were obtained by calculating the C value between 1.05 and 1.50 according to the maturity formula in Correlation (1) below. Linear regression was applied between the compressive strengths for the C value to be determined for fresh concrete and the maturity values obtained for C value (1.05–1.50). The final C value was obtained from the regression values of 1.05 and 1.50, giving the highest regression value. As a result of the regression analysis of the compressive strength of the samples at 20 and 65°C, the C value for the structural concrete samples in this study was found to be 1.05 as shown in Figure 3.

Figure 3. Determination of C value in fresh concrete

After the C value calculated for the compressive strength prediction by weighted maturity method, the compressive strength test of the samples taken in the laboratory environment was applied at certain time intervals and the corresponding maturity values at the time when the compressive strength test was applied were determined and the calibration curve was formed.

Figure 4. Calibration curve generated for maturity device

According to the C value and calibration curve, the device used for the Weight Maturity Method was adjusted and the pressure strength estimation measurements were made in the field concretes (Figure 5. (a), (b)).

Figure 5. (a) Connecting the temperature sensors to the maturity device, (b) Placing the temperature sensors to the concrete manufacturing in the dam.

2.5. Sampling of Core Drilling and Measurement of Compressive Strength of Concrete

28 days later the concrete productions cast in the field, cores with a nominal diameter of Ø100 coring blade and 15 cm length were taken according to TS 10465 standard as shown in Figure 6 [15]. The length / diameter ratio of the core samples was cut to 1.5 / 1 and the cores were made a cap. Genuine concrete strengths were measured on these samples.

Figure 6. Core samples

3. Result and Discussion

Figure 7 shows the average compressive strengths measured on cylinder samples of $\phi 15 \times 30$ cm cylinders belonging to 10 different C25/30 building constructions, the estimated compressive strengths in the concrete productions with the maturity device and the compressive strengths of the cores taken from the concrete productions. The values estimated by the maturity method correspond to the compressive strength of the 15 cm cylinder concrete sample. In Figure 14, when the pressure strengths of fresh concrete samples are compared with the measurements in the maturity device, the maximum error rate is 7% at early ages, 3% on the 28th day, and when the pressure strengths of the core samples taken from the concrete equipment measurements at the maturity device are compared, the maximum error rate is 7% at the 28th day. This indicates that the accuracy of the maturity estimation with maturity device is quite low. Lyul Cha et al. (2018) estimated the elastic modulus and compressive strength of the concrete at an early age with the maturity device and observed that there was a 10% error rate.

Figure 7. Test results according to compressive strength determination methods of C25/30 concrete productions

The compressive strength values measured by 3 different methods of C25/30 building concrete manufacturing are close to each other. The compressive strengths measured from core samples are missing 15% of the compressive strengths measured from fresh concrete samples [17]. Since the concrete is stored in the curing pool in the optimum temperature and curing environment, the strength of these concrete is higher than the field concrete. Figure 1 shows that the 28-day strength difference in laboratory and core samples is consistent with the literature. In this study, it was found that the resistance values of the pressure values measured from the maturity device were found to be between 15% and 20% of the strength values measured on core samples. Destructor and Chen placed 1.8x1.8x1.8 m cube mold at different points with the help of temperature sensors by using the method of maturity by measuring the pressure resistance, compared to the compressive strength of the cores taken from the concrete method and obtained the error rate of $\pm 15\%$ of the pressure resistance estimates obtained by the maturity method [18]. In this study, when the compressive strengths of the C25/30 building concretes were compared with the values obtained from fresh concrete samples and core samples, it was found that the use of maturity equipment was an appropriate method. The determination of the strength of concrete in the field by weighted maturity method is easier in practice than taking the sample from fresh concrete and determining the compressive strength.

4. Conclusion

In this study, the following results were obtained.

1. Maturity device is a method that can be used in concrete manufacturing. The estimated compressive strength measured in building concretes corresponds to the compressive strength measured from core samples in the field.
2. With this study, it is understood that under heavy construction site conditions, workers will be prevented from lifting the samples in heavy load according to occupational health and safety measures and

it is not necessary to remove excess materials from concrete in the method such as weighted maturity.

3. It is known that the cores taken from the building concrete manufactures to learn the actual compressive strength are damaging to the buildings and with this research, the compressive strengths of the concrete are estimated without damaging the structures by means of temperature sensors placed in the concrete manufactures.

4. In this research, the development of early compressive strengths from the internet was observed by the maturity device and it was found that the maturity device is useful in the structures that need early molding.

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References

- [1] Dehestani, M., Nikbin, I.M. and Asadollahi, S., 2014. Effects of specimen shape and size on the compressive strength of self-consolidating concrete (SCC). *Construction and Building Materials*, 66, 685-691.
- [2] Şanal, İ., 2018. Detailed examination of the shape-size effect for the widespread use of small cubic concrete samples in concrete compressive strength tests. *Dokuz Eylül University-Faculty of Engineering Journal of Science and Engineering*, 20, 103-120, DOI: 10.21205/deufmd.2018205809.
- [3] Amin, M.N., Su Kim, J., Lee, Y. and Keun Kim, J., 2009. Simulation of the thermal stress in mass concrete using a thermal stress measuring device. *Cement and Concrete Research*, 39, 154-164.
- [4] Boubekour, T., Ezziene, K. and Hadj Kadri, E., 2014. Estimation of mortars compressive strength at different curing temperature by the maturity method. *Construction and Building Materials*, 71, 299-307.
- [5] Lyul Cha, S., Seop Jin, S., Hee An, G., and Keon Kim, J., 2018. A prediction approach of concrete properties at early ages by using a thermal stress device. *Construction and Building Materials*, 178, 120-134.
- [6] Ferreira, L., Branco, F.G., Costa, H.S.S., Julio, E. and Maranha, P., 2015. Characterization of alkali-activated binders using the maturity method. *Construction and Building Materials*, 95, 337-344.
- [7] Deşik F. 2019. Estimation of compressive strength of concrete by sample form, size relationship and weighted maturity method. Recep Tayyip Erdogan University Master Thesis, Rize.
- [8] Teixeira, S., Santilli, A., and Puente, I., 2017. Demoulding vertical elements: recommendations for apply maturity functions. *Construction and Building Materials*, 145, 392-401.
- [9] Topçu, İ.B. ve Akman, A., 2005. Determination of mold removal time by maturity. *Earthquake Symposium, Kocaeli*, 23-25 Mart, 864-869.
- [10] Sağlık, A., Özbay, H., Soysal, H.İ. ve Ergin, Ç., 2015. Betonda olgunluk yönteminin kullanılması ile ileri yaşlardaki yerindeki beton dayanımının tahmini. DSİ TAKK Dairesi Başkanlığı Kalite Kontrol Sempozyumu, İstanbul, 30 Kasım-4 Aralık, 2-17.
- [11] Galobardes, I., Cavalaro, S.H., Goodier, C.I., Austien, S. and Rueda, A., 2015. Maturity method to predict the evolution of the properties of sprayed concrete. *Construction and Building Materials*, 79, 357-369.
- [12] TS EN 12350-2, 2010. Concrete - Fresh Concrete Tests - Part 2: Slump Test. TSE, Ankara, 6s.

- [13] TS EN 12350-6, 2010. Concrete - Fresh Concrete Tests - Part 6: Density. TSE, Ankara, 8s.
- [14] TS EN 12350-7, 2010. Concrete - Fresh Concrete Tests - Part 7: Determination of Air Content - Pressure Methods. TSE, Ankara, 6s.
- [15] TS 10465, 2010. Concrete Test Methods-Sampling of Hardened Concrete in Building and Structural Components and Determination of Compressive Strength. TSE, Ankara, 12s.
- [16] TS 13508, 2012. Estimation of Concrete Strength by Maturity Method. TSE, Ankara, 30s.
- [17] TS 13791, 2012. Determination of Compressive Strength in Structures and Precast Concrete Components. TSE, Ankara, 25s.
- [18] Yıkıcı, T.A. and Chen, R., 2015. Use of maturity method to estimate compressive strength of mass concrete. Construction and Building Materials, 95, 802-812.

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