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Geleneksel ve Yüksek Dayanımlı Betonların Dayanımının İncelenmesi

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Özet: Son otuz yıldır kullanılan ve teknolojik gelişmeler sayesinde popülerlik kazanan çekme dayanımı arttırılmış beton üzerine yapılan çok sayıda araştırma çalışmasına rağmen, betonun spesifik özellikleri geleneksel betona göre daha az anlaşılmaktadır. Betonarme kullanımıyla ilgili yönergelerin çoğu, çekme dayanımı 50 MPa'ya kadar olan beton üzerinde yapılan araştırmalara dayanmaktadır. Bu çalışma, hem geleneksel hem de yüksek dayanımlı betonun çekme dayanımının çeşitli kurutma yöntemleriyle nasıl değiştiğini araştırmayı amaçlamaktadır. Bulgular, yetersiz kurutma sonuçlarının dayanım sorunlarına yol açtığı inancının aksine, betonun kurutulduğu sıcaklıktaki değişikliklerin her iki tipte de dayanım artışını etkilediğini ortaya koymaktadır. Suda hiç kür yapılmayan numunelerde yüksek dayanımlı betonun 28 günlük basınç dayanımı, soğuk ortama göre %7 oranında arttı. Bu artışlar W/C=0,50 olan konvansiyonel beton için %14, W/C=0,70 olan konvansiyonel beton için ise %11 olmuştur. Standart ortamda kürlenen yüksek dayanımlı betonlarda 90 günlük numuneler, 28 günlük numunelere göre %19 oranında dayanım artışı sağlamıştır. Aynı oranlar W/C=0,50 olan geleneksel beton için %0, W/C=0,70 olan geleneksel beton için ise %15 idi. Sonuç olarak, hem yüksek dayanımlı hem de geleneksel beton kuruma koşullarına benzer tepkiler verirken, dayanımlarını arttırmada sıcaklığın etkisinin yetersiz kurutmadan kaynaklanan sorunlardan daha önemli olduğu sonucuna varılmıştır. Benzer araştırmaların diğer beton çeşitleri üzerinde de sürdürülmesi gerektiğinin altını çizmek önemlidir.

Anahtar Sözcükler: *Basınç Dayanımı, Farklı Kür Koşulları, Geleneksel Beton, Mukavemetli Beton.*

Examining the Strength of Traditional and High Strength Concretes

Abstract: Despite numerous research efforts on concrete with enhanced tensile strength, which has been utilized for the past three decades and has gained popularity due to technological advancements, its specific properties remain less understood compared to conventional concrete. Most of the guidelines for using reinforced concrete are based on research conducted on concrete with tensile strengths of up to 50 MPa. This study aims to explore how the tensile strength of both traditional and high-strength concrete changes with various drying methods. The findings reveal that variations in the temperature at which the concrete is dried affect the strength increase of both types, contrary to the belief that insufficient drying results lead to strength issues. In conclusion, while both high-strength and traditional concrete demonstrate similar responses to drying conditions, it's concluded that the impact of temperature is more significant in enhancing their strength than any problems caused by insufficient drying. It's important to highlight that similar research on other concrete varieties should be pursued.

Keywords: Compressive Strength, Conventional Concrete, Different Curing Conditions, High Strength Concrete.

1. Introduction

From the second half of the 19th century, when concrete and reinforced concrete were invented, to the present day, concrete of a quality superior to the standard concrete produced in every period; It could be achieved with improvements in materials and technology of the day.
However, all parameters affecting concrete strength must be known. One of these parameters is the curing conditions applied for the maintenance of concrete. The composite material obtained by blending cement, aggregate, water and, when necessary, an additive, placing a mixture with carefully adjusted proportions into molds of the desired shape and size without gaps and hardening under appropriate maintenance conditions, is called concrete or traditional concrete.

High strength for a special type of concrete that requires quality cement and aggregate, super plasticizer additive and silica fume, and maintains its high workability (slump value up to 20 cm) and pump ability even though the water-cement ratio is reduced to 0.20 and the compressive strength is increased to 100 N/mm^2. It is called concrete (Kocataşkın 1991). It is necessary to keep the cement dosage between 300-350 kg/m3 for conventional concrete and 400-500 kg/m^3 for high strength concrete (Dahil 2001).

In concretes with high strength properties, similar to those in conventional concretes, opting for drinking water in the concrete mixing process is the optimal choice. However, utilizing water that has been previously tested and produced satisfactory outcomes is not detrimental. Although the initial compressive strength of concrete is lower compared to its strength after 3 months or beyond, the latter strength increases significantly. The incorporation of silica fume in concrete enhances the early concrete strengths surpassing that of the control concrete, allowing for the achievement of remarkably high compressive strengths with the addition of fly ash and/or silica fume.

Generally, concretes with a 28-day compressive strength greater than 40 N/mm^2 are defined as high strength concrete. Concrete strength generally depends on the cement paste void structure, the properties of the aggregate and the characteristics of the aggregate-cement paste transition zone. In order to reduce the amount of voids in the cement paste and transition zone without worsening the workability of concrete, the use of water reducing additives can be considered together with increasing the cement dosage. Cement dosage can exceed 600 kg/m^3.

Pumice is used to prevent the formation of $Ca(OH)_2$ crystals to obtain high-strength concrete. It is known that pumices react with $Ca(OH)_2$ and form new elements similar to other hydrated elements in cement. The Poisson ratio of high-strength concrete under elastic loading can be compared with the Poisson ratio of low-strength concrete. This ratio varies between 0.18 and 0.24 depending on the stress level (CEB 1990). For the calculation of Poisson's ratio, Ahmad (ahmad and shah 1987) suggested using the equation ν=6.855(fc)-0.77 (MPa) for Poisson's ratio. In addition, according to the test results of concretes with compressive strength between 21 MPa and 76 MPa, the Poisson ratio of concretes made of gravel or limestone can be taken as 0.2, regardless of their compressive strength (Ersoy 1991; Üzümeri and Özden 1991).

There are many sources about the shrinkage properties of high-strength concrete. Aitcin observed that in three high-strength concrete groups with compressive strengths of 64 MPa, 90 MPa and 100 MPa, the initial shrinkage rate was relatively higher for high-strength concrete. Studies on the relationship between concrete compressive strength and creep coefficient have shown that the maximum inherent creep in concrete of the same age is less for high-strength concrete than for conventional concrete. Additionally, the creep behavior of concrete depends on the curing regime applied to the concrete. Low w/c ratio and high degree of hydration at loading time are factors that reduce the creep potential (Ersoy 1991; Üzümeri and Özden 1991). In another research research detailed the method of testing with unstressed residuals, aiming to ensure consistency and establish a standard for comparison (Babalola et al 2021).

It has been proven by many researchers that the elastic modulus of high-strength concrete cannot be calculated accurately with the equations given in the regulations today. It is understood that the relationship between tensile strength and compressive strength of high-strength concrete is different from conventional concrete. Although additional research is required on this subject, the equations given in the regulations today can be considered valid (Ersoy 1991; Kocataşkın 1991; Kocataşkın 1991; Pul 1999; Balta 1991; Dahil 2001; Özkul and Karagüler 1991; CEP 1990; ahmad and Shah 1987; Üzümeri and Özden 1991). Studies on high-strength concrete show that as concrete strength increases, the σ-curve, which determines the stress-strain relationship of concrete, changes significantly. Some experimental studies have been conducted to examine the effect of confinement reinforcement in high-strength concrete. It has been proven in beam tests performed by applying simple bending and in some analytical studies that ductility can be effectively increased with confinement reinforcement. It has been understood through experiments that the moment-curvature relationship determined by known methods for beams is also valid for beams (Ersoy and Tangut 1991).

In the Standard Belgian Articulated Beam Tests, Maton (Maton 1988) observed that the loads obtained in response to the maximum shear in high-strength concretes were greater than in conventional concretes, and argued that the adherence of thick reinforcement was lower than that of thin reinforcement. In the research of De Larrard and Malier, it is claimed that this situation can only be explained by inherent shrinkage (Lallard and Malier 1991).To address the problem of steel rusting in traditional reinforced concrete (RC) structures, especially in sea-based areas, using glass fiber reinforced polymer (GFRP) bars in concrete that contains sea-sand has become more common because of their outstanding resistance to corrosion (Zeng at all 2022).

Larrard (Lallard and Malier 1988) observed that the crack widths were lower in high-strength concrete floor slabs by working the reinforcement of floor slabs working in a direction with conventional and high-strength concretes up to the maximum stress value. As the compressive strength of concrete increases, the modulus of rupture increases proportionally. Therefore, in the mentioned calculation method, the effect of concrete compressive strength should be reflected in the calculation of the minimum tensile steel ratio. Based on this, the formula $\rho_{min}=(0.225\sqrt{fc})/fy$ (MPa) is recommended. Besides, Nilson (Nilson 1987) said that a larger ratio was required and gave the formula $\rho_{min}=(0.250\sqrt{fc})/fy$ (MPa) (Üzümeri and Özden 1991). In recent years, numerous studies have been carried out on the physical behavior and chemical characteristics of concrete produced using steel slag at room temperature (Hop et al 2022).

Three different methods are used to obtain high strength concrete. The first of these is the Metha – Aitcin method and the main principles are as follows:

In order to provide the desired compressive strength, workability and volumetric stability for high-strength concrete, the optimum cement paste should be 35% by volume.

The slump and maximum aggregate size appear to be unimportant as long as the slump is controlled by the amount of superplasticizer.

Mineral additives are necessary to ensure economy.

The optimum volumetric ratio between fine and coarse aggregate is 65%.

The second method is the Toralles Carbonari method and its main principles are as follows:

- This method argues that high-strength concrete can be produced with optimum cementitious materials and aggregates. It states that it is an ideal mixture with minimal space between fine and coarse aggregate.
- The third method is the Aitcin method and the main principles are as follows:
- It has the same approach as ACI 2111 Standard Practice for Selecting Proportions for normal, heavy and mass concretes. It is a combination of empirical results and mathematical calculations based on the approximate volume method

2. Material And Method

Under this heading, the strength development of traditional and high-strength concretes under different curing conditions is examined. For this purpose, central pressure tests were carried out on cube samples produced.

2.1. Properties of the Materials Used in the Experiment

2.1.1. Properties of Aggregates

This specific kind of aggregate was utilized in both standard and robust concrete manufacturing processes. The aggregate in question, "limestone," was sourced from the Trabzon area and prepared into thin sections by K.T.Ü. in the Department of Geological Engineering, where studies were conducted to identify its mineralogical characteristics (Hüsem 1995). A photograph illustrating the aggregate in question is depicted in Figure.1.

Figure 1. Limestone aggregate used in experiments

The limestone rock described earlier was taken from the crusher to the KTÜ Civil Engineering Department Building Materials Laboratory. In this case the sieve system follows the guidelines in TS 1226 ISO 3310-2 and TS 1227 ISO 3310-1 (TSE 1996) as stated in TS EN 12620 (TSE 2003). The biggest grain size that can pass through the sieve is 16 mm and only grains that are 16 mm in size or smaller will be sifted. There are three sizes of particles: large (more than 8 mm) medium (between 8 mm and 4 mm) and fine (less than 4 mm). The table 1 shows values for the weight of individual particles how much water they can hold and how heavy they are when wet or dry. These values were measured using specific methods outlined in TS EN 1097-6 (TSE 2002) and TS 3529 (TSE 1980).

Table 1. Physical properties of limestone aggregate

Aggregate type	**Aggregate class**	**Loose unit mass (mm)**	**Specific mass (kg/m^3)**		**Water absorption by mass(%)**
			Dry	**Saturated**	
Limestone	**Big(16-8mm)**	**1400**	2658	2670	0.42
	Mid.(8-4mm)	**1400**	2658	2670	0.42
	Small (4-0mm)	**1450**	2626	2640	0.52

The granulometric composition of limestone aggregate used in the production of traditional and high strength concretes is shown in Figure 39. This granulometry was obtained by mixing coarse, medium and fine aggregates at 35%, 30% and 35% by mass, respectively.The strength of beams was discovered to enhance due to the incorporation of PET waste fiber, however, it is not possible to boost the maximum load strength (Mohammed et al 2020).

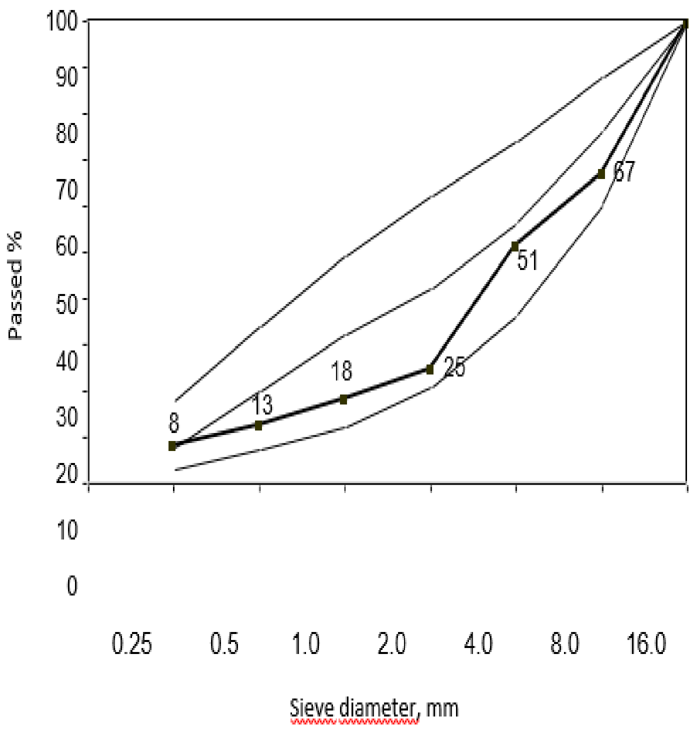

Figure 2. Granulometric composition of aggregate used in the construction of concrete

2.1.2. Properties of the Cements Used

CEM II A-P 32.5 R cement produced according to TS-EN 197-1 (TSE 2006) in Aşkale Cement (Trabzon) Factory in the production of traditional concretes and TS-EN 197-1 (Hüsem et al 2006) in Ünye Cement Factory in the production of high strength concretes. Advanced algorithms for supervised machine learning are becoming increasingly popular for forecasting the mechanical characteristics of concrete (Farooq et al 2020). CEM I 42.5 R cement produced according to was used. The chemical, physical and mechanical properties of these cements obtained from the factories where they are produced are given in Table 2.

Table 2. Physical properties of limestone aggregate

PHYSICAL PROPERTIES	Percent by Mass (%)	
	CEM II A-P 32.5 R	CEM I 42.5 R
Specific Mass (g/cm^3)	2.90	3.05
Specific Surface (Blaine) (cm^2/g)	4246	3755
90 µ remainin on the sleve (%)	2.0	0.1
Setting time (hour) (index of Vicat Beginning	02.50	02.41
Setting time (hour) (index of Vicat Finish	04.00	04.11
Standard consistency water amount (%)	33.13	29.50
MECHANICAL SPECIFICATIONS		

2 days	Compressive strength (N/mm^2)	18.5	26.7
7 days	Compressive strength (N/mm^2)	29.9	44.3
28 days	Compressive strength (N/mm^2)	37.0	51.4
CHEMICAL PROPERTIES			
	SiO_2	26.48	19.78
	Al_2O_3	5.94	5.83
	Fe_2O_3	3.90	3.37
	CaO	51.54	61.90
	MgO	2.30	1.10
	SO_3	2.21	2.59
	Loss of glow	6.10	3.70
	Cl^-	0.027	0.0127

2.1.3.Properties of Silica Fume Used

Silica fume (light micro silica) and superplasticizer additives have been used in the production of high-strength concretes. The chemical properties of the silica fume used are shown in Table 3.

Table 3. Chemical properties of silica fume

Chemical Properties	Percent by Mass (%)
Soluble SiO_2	92.82
Insoluble SiO_2	0.58
Al_2O_3	0.35
Fe_2O_3	0.54
CaO	2.30
MgO	1.09
SO_3	-
Loss of Glow	1.31
Undetectable	1.01
Stacked Density (cm^3/gr)	0.28

2.1.4. Characteristics of the Mixed Water Used

The chemical properties of drinking water used in mixing concrete were determined in the KTU Chemistry Department. These chemical properties are given in Table 4.

Table 4. Chemical properties of the mixed water used

Components	Quantities (mg/lt)
Na^{+}	50.00
K^{+}	0.80
Ca^{+2}	100.80
Mg^{+2}	6.72
Fe^{+3}	3.00
Cl^{-}	125.00
$(SO_4)^{-2}$	45.00
$(HCO_3)^{-}$	210.00
Total number of cation m.e.g.	7.90
Total number of anion m.e.g.	8.10

2.2. Composition of Concretes

The absolute volume method was used in the composition calculations of traditional and high strength concrete. Related with this work investigates the degradation mechanisms of Clinkerless alkali-activated slag based ultra-high strength concrete (AAS-UHSC) upon exposure to high temperatures up to 800°C (Cai and Clinkerless).Wc, Wa, Vw and Vh represent the cement mass (kg/m^3), aggregate mass (kg/m^3), water volume (dm^3) and trapped air volume (dm^3) in 1 m^3 of concrete, respectively; γc and γa represent the saturated dry surface content of cement and aggregate, respectively. Absolute volume of aggregates to indicate their unit mass (kg/dm^3):

$$Va = Wa/\gamma a = 1000 - (Wc/\gamma c + Vw + Vh) \quad (1)$$

It is calculated by the formula. Considering that the aggregate consists of i separate aggregate classes, the mass of each aggregate class will be separate, βi and γai are the total aggregate mass to show the mass ratio of each aggregate class and the saturated dry surface unit mass, respectively;

$$\sum (\beta i \times Wa/ \gamma ai) = 1000 - (Wc/\gamma c + Vw + Vh) \quad (2)$$

It is calculated with the formula. When the total aggregate mass calculated from this formula is multiplied by the mass ratio of each aggregate class, the masses of each aggregate class are determined separately.

$$Wai = \beta i \times Wa \quad (3)$$

Another research project was conducted to create testable formulas for forecasting the physical characteristics of strong concrete (HSC), including the combined impact of silica fume, the size of aggregates, the ratio of water to cementitious materials, and the duration of the curing process (Davood et al 2023).The aggregate masses obtained in this way are saturated dry surface aggregate masses. To find the aggregate mass values in natural humidity from these values, SEi and DNi are the amount of saturation water required for each aggregate class to show the mass water absorption and natural moisture rates for each aggregate class, respectively;

$$DSi = (SEi - DNi) \times Wai \quad (4)$$

It is calculated with the formula. Total saturation water is the amount of saturation water of each aggregate class.

$$DS = \sum DSi \quad (5)$$

The technique described above helped determine the amount of water and cement needed for both regular and high-strength concrete. Hakeem and his friend are doing a study to see how adding nanosilica (NS) affects the qualities of environmentally friendly strong concrete (SHSC) (Hakeem et al 2023). In traditional concrete the water-to-cement ratio is 0. 50 and 0. The amount of cement used was 300 kilograms per cubic meter and the water to cement ratio was 0 in strong concrete mixes. The calculations included 500 kg/m^3 of cement. In the high-strength concrete mix they also added 10% of silica fume and 2% of superplasticizer admixtures by weight of cement + silica fume. The determined concrete compositions are given in Table 5 below.

Table 5. Compositions of Concretes

Concrete Type	Total aggregate/ m^3	Saturation water kg/m^3	Mixture water kg/m^3	Cement g/m^3	S/Ç	SD kg/m^3	SAK kg/m^3
High Strength	1622	40	165	500	0.33	50	11.0
Traditional	1878	46	150	300	0.50	--	3.0
	1724	42	210	300	0.70	--	--

The concrete produced using the materials detailed above was poured into molds under laboratory conditions and this is shown in Figure 2.

Figure 2. A view of concrete poured into many molds

3. Results and Discussion

If we compare samples that were left to dry in the air with those that were never put in water after being taken out of the mold;

Samples stored in a place with a temperature of 25 0C ± 2 0C are stronger than samples stored in a cold place (13˚C ± 2˚C). For high strength concrete the strength is 19% higher after 3 days 7% higher after 7 days 7% higher after 28 days and 8% higher after 90 days. has become stronger. So when there's a 12˚C difference in temperature between two places high-strength concrete gets about 10% stronger and regular concrete with a certain ratio gets about 12% stronger. In regular concrete the amount of a certain material is 0.26 times its weight which is equal to 50. 70- resulted in (refer to Figures 52 56 and 60). The variations in these increases can be understood by looking at the different amounts of heat released when concrete sets. Other cure conditions also showed similar variations. In the another research is to examine how substituting all the fine and coarse aggregates with denser aggregates impacts their protection against radiation and changes their physical and flow characteristics when added to a mixture of concrete high in strength and density (Khaled et al 2024) .

When the bar diagrams given for all other hot environment and cold environment cures, where they were kept in water for a certain period of time and then kept in air until the test, were evaluated together; Compared to cold environment curing, hot environment curing caused an average strength increase of 10% in high strength concrete, an average of 14% in conventional concrete with W/C = 0.50, and an average of 34% in conventional concrete with W/C = 0.70.

Based on the 28-day strength of concrete cured in standard environments; In high-strength concrete, concrete that remained in water for 28 days gained 21% more strength than concrete that was never immersed in water. The same rates are 24% for conventional concrete with W/C=0.50 and 40% for conventional concrete with W/C=0.70. If a similar comparison is made for a cold environment, it is 17% in high strength concrete, 16% in conventional concrete with W/C = 0.50 and 10% in conventional concrete with W/C = 0.70.

As it is known, in order to obtain quality concrete, all three stages of production, placement and curing must be carried out properly and carefully. Therefore, the change in strength that occurs with the change of ambient temperature in samples that are always cured in air, becomes even more important in our country since the cure phase is generally the stage that is given the least attention in the concrete industry. In practice, since concrete is mostly left alone after being poured and placed, it turns out that the most suitable season for concrete pouring is spring. Preceding the predictability of concrete's compressive strength presents substantial difficulties due to its natural intricacy. Nonetheless, this research effectively applied machine learning methodologies to precisely forecast the compressive strength of high-strength concrete (Kumar and Bheem 2024).

The 28-day concrete strengths obtained in standard and cold environments in all productions and the concrete classes determined based on these strengths are given in Table 6.

Table 6. Obtained 28-day strengths and concrete classes

Concrete	Cure environment	28-day average cube strength (MPa)	Standard deviation (MPa)	Characteristic cube strength (MPa)	Equivalent standard cylinder strength (MPa)	Concrete class
High Strength (W/C=0.33)	Standart	75	4.00	70	56.0	C55
	Cold	68	3.60	63	50.4	C50
Classical (W/C=0.50)	Standart	27	2.10	24.3	19.44	C20
	Cold	22	1.66	19.9	15.9	C16
Classical (W/C=0.70)	Standart	20	1.20	18.5	14.8	C12
	Cold	14	0.85	12.9	10.3	C10

4. Conclusion and Suggestions

In this research, the progress in strength enhancement of conventional and advanced-strength concretes under various curing treatments was explored through experiments. Following the experimental schedule set for this research, a total of 234 cubic concrete samples, each measuring 150 mm on each side, were created into 6 distinct groups. These samples underwent a central pressure test. The findings from both the experimental and theoretical research conducted on the concrete samples classified as C55, C20, and C12 are presented in detail. In samples that were not cured in water at all, the 28-day compressive strength of high-strength concrete increased by 7% compared to the cold environment. These increases were 14% for conventional concrete with W/C=0.50 and 11% for conventional concrete with W/C=0.70. The reason why the strengths of high-strength concretes, which are never cured in water (always cured in air), are lower than the strengths of conventional concretes, is that the C-S-H gel (tobermorite gel) can not be formed sufficiently due to the low amount of water due to S/C damping. In high-strength concrete cured in a Standard environment, 90-day-old samples provided a 19% increase in strength compared to 28-day samples. The same rates were 0% for conventional concrete with W/C=0.50 and 15% for conventional concrete with W/C=0.70. Here, the reason why the strength of high-strength concretes in the standard (curing pool) environment is higher than the strength of conventional concretes is that the silica fume used in the production of high-strength concretes creates a more compact structure in the concrete and strengthens the structure by creating additional C-S-H gel (tobermorite gel).

To sum up, while the same types of behaviors were seen in both high-strength and standard concretes that were cured in various settings, it was found that the impact of the difference in curing temperature on the strength growth outweighed the disadvantages of curing in water. It's important to mention that carrying out similar research on various concrete types could prove to be advantageous.

CONFLICT OF INTEREST

It is stated whether there is a conflict of interest between the authors.

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