NWSA-Technological Applied Sciences
ISSN: 1306-3111/1308-7223
NWSA ID: 2014.9.3.2A0087
Status : Review
Received: January 2014
Accepted: July 2014
E-Journal of New World Sciences Academy

Zuhal Şimşek
Uludağ University, zumanav2002@hotmail.com, Bursa-Turkey

http://dx.doi.org/10.12739/NWSA.2014.9.3.2A0087

FIRE RESISTANT CONCRETE DESIGN

ABSTRACT

To minimize loss of life and property, structure of building should be established to allow time for evacuation from place location of the fire and to provide the structure and prevent the collapse of buildings having high fire risk rate. Considered most of buildings made by concrete in our country, integrity of concrete must be provided during the time period escape from fire. Particularly, buildings and fire compartments having high fire risk, must be designed to provide high strength and to minimize the loss of goods. Forming fireproof compartments may be accomplished by, treatment of the weak points and determinating temperature changes on the concrete components. Fire resistance of concrete increased by adding puzzolan additives. In the study, behavior of concrete exanimate at different temperatures and optimal concrete composition evaluated. Use of such concrete built with laboratories and flammable and chemical gases or liquids stores, will reduce the life losses significantly. Moreover, studies in the light of the findings obtained that, usage of concrete in those locations has a great significance, in the creation of a secure environment during evacuation and quenched period.
Keywords: Concrete, Fire Resistant, Puzzolan Additives, High Performance concrete, Durability

YANGINA DAYANIKLI BETON TASARIMI

ÖZET

Yangının oluştuğu mekânının terk edilmesine olanak sağlayacak sürede, yapının taşıyıcılığının sağlanmalıdır. Dolayısıyla beton, kaçış süresi boyunca bütünlüğünü koruyacak ve yapının çökmesinin engellenecek şekilde tasarlanmalıdır. Yangına dayanıklı kompartımanların oluşturulması, sıcaklığın beton bileşenleri üzerinde oluşturduğu değişimlerin belirlenerek, zayıf noktaların iyileştirilmesi yolu ile gerçekleştirilebilir. Betonun içine ilave edilen puzzolan katkılar yolu ile yangın dayanımı arttırılabilmektedir. Çalışmada, bu katkıların hangi sıcaklıkta nasıl olumlu davranışları oluşturduğu incelenerek, yangın kompatımanlarının kullanılan en ideal beton bileşimi değerlendirilmiştir. Yangın anında yangın yükü fazla olan mekanlar ile yanıcı ve parlayıcı kimyasal gazların veya sıvıların bulunduğu laboratuvar ve depolarda, söz konusu nitelikte beton malzemenin kullanılması can ve mal kayıplarını önemli ölçüde azaltacaktır. Ayrıca, çalışma sonunda elde edilen tespitler ışığında belirlenen özellikte betonun kullanılması, bu mekanlarda tahliye ve söndürülmesi sırasında geçen süre boyunca güvenli bir ortamın yaratılması konusunda büyük bir öneme sahiptir.
Keywords: Beton, Yangın dayanımı, Puzzolan katkılar, Yüksek dayanımlı beton, Durabilite

1. INTRODUCTION (GİRİŞ)

Fire is a physical event which is difficult to extinguish once started and most of the time compensatory damages and losses to be formed by is impossible. A building exposed to fire-fighting continues, long hours, and then service of the building after the disaster has become impossible. The loss of life and property are bigger when the structure of building fails before evacuating all of the users. And it shall be also provided that to minimize damages caused by fire, to ensure sustainability of performance after fire and to have a value of compressive strength allowing users to evacuate in time to ensure survival during the fire. Especially in our country, a large part of the buildings are constructed as concrete structures. Because of this fact, concrete must be designed to provide high performance which is used in buildings having high risk of fire, building structure and in fire compartments.

At high temperatures, the most important mechanisms that effect losing the values of the compressive strength of concrete and bearing capacity are losing the quality of components in the concrete microstructures which occurs at the end of chemical reactions and creating surface cracks and explosions. The best optimal mix of concrete should aim to provide desirable thermal properties while struggling to minimize the potential for explosion fragmentation and decreasing the values of compressive strength.

For this purpose, the integrity of concrete's heating, cooling, and the next phases that affect environmental and mass factors and mechanisms, including a study by doing global approach to addressing these missing aspects of the material should be developed. Concrete aspects of these missing can be developed into 2. The behavior of concrete at high-temperatures can be improved the way of:

- Choosing components to develop the properties of at high temperatures.
- Adding polypropylene fiber and puzzolan admixtures in to concrete mixture, (creation of HPC).

In the first stage, a negative impact of high temperatures values upon concrete must be detected and must be developed in the missing direction.

2. RESEARCH SCITIFICANCE (ARAŞTIRMANIN ÖNEMİ)

User safety can only provided by maintaining integrity of the structure of the building. In our country, most of the buildings are constructed of reinforced concrete. Therefore, knowledge of fire behavior of concrete being well, is the first step of fire-resistant construction. It is expected to remain stable of integrity of the concrete. Such as hospitals where people cannot move alone and high-rise buildings that will take a long time to evacuate, at high temperature. Concrete should be used having more stable behavior against. Especially in fire resistant compartments and high fire load places or high risk of explosion buildings. Concrete is a composite material. Therefore, fire-resistant materials can be produced as a result of determination and improvement of concrete components behavior against fire. In the study an ideal component for concrete were investigated in such building and compartments. It is considered that this review can be an example of selection of concrete components in fire compartments and high fire risk places.

3. NEGATIVE EFFECTS ON CONCRETE FORMED BY FIRE (YANGININ BETON ÜZERİNDEKİ OLUMSUZ ETKİLERİ)

As a result of temperature increases, in physical and chemical negativities occur in structure of concrete. In the first stage from the physical point of a change is observed in the color of concrete in certain temperature limit. But this negativity, does not significantly effect the structural properties. However if we look at the the chemical changes in the concrete structure, explosive spalling, integrity and losing bearing capacity is seen as an important problem. Therefore, concrete which is used in construction of high fire risk structures, should be designed to allow to protect the integrity and bearing capacity of the building during the period of evacuation of all users to the outside of the building or safe compartments. Hence, the concrete needs to be created that may have minimum damage after fire or to continue bearing capacity at least at the end of a possible fire. Therefore it is important to know how concrete perform such temperature value. Only with this way we can improve the behavior of concrete that exhibit against fire.

The temperature degree that concrete integrity can remain stable should be designated depending on the function of the place. Concrete which is used in to create fire compartments and in the will be likely to have high fire risk places structural systems, should be protect load-carrying without impairing the structural integrity capacity to the highest temperature. In addition, it is important in the way of to reach users to secure point of the building before collapse the structure of the building.

Also the protection of concrete integrity and bearing capacity up to high temperature degrees is important to determine the reach of the inhabitants to the secure points before collapse of building.

Therefore, concrete used in this places, should maintain aggregate and cement that continue the value of durability of concrete to the top-up to temperature and certain proportions of puzzolan additives should be added to the mixture to receive higher values of the upper temperature limit. To improve the behavior of concrete against fire with these methods:

- 1. stage, it is determined how mechanisms occur at which temperature values within the concrete, depending on the type of selected aggregate and cement.
- 2. stage; it is determined what proportions and what kind of components should be used to improve these drawbacks, and at which temperature values how they react.

3.1. Determination of the Behavior of the Components against Fire (Bileşenlerin Yangın Karşısındaki Davranışlarının Tespit Edilmesi)

On the basis of concrete features at 600C^0 and upper degrees protecting the integrity of the structure even continue to bearing capacity is selecting components having flat-footed behavior against fire. Therefore, aggregates which are not fragile at high temperatures and binders having least by-products as a result of dehydration should be selected for concrete composition. And it should be based on granometric mixture that allows formation of voids that will allow for storage of these products. Therefore the most important factors of concrete be able to serve after fire and through a serious economic repair and to review seriously affecting the economic repairs are to prepare the most ideal concrete mix and to choose the aggregate and cement having best behavior against fire. In this respect the aggregate and cement properties should have, are listed below.

3.1.1. Aggregate (Agrega)

To provide performance against fire for aggregates flowing features should be taken into consideration.

- Thermal stability,
- The strong bond between cement and aggregate and
- Properties of reactivity.

If the temperature keeps constant in the face of aggregates, high resistance can provide with the bond occurred between the cement paste against [8].

If thermally stable aggregates creating a bond between cement paste, suffer damage under high temperatures, concrete can also suffer damage. If the chemical bond occurred between the aggregate and cement paste, became weakness due to the deterioration of heating the chemical structure during the process and the thermal mismatch between aggregate and cement paste, strength of concrete is felt weak. Being weakness of aggregate and cement paste, naturally a weak bond would result between them. So that when making selection of aggregate these features should be taken into consideration.

- Gravel and coarse sand expand 0%, 7- 1, 4 values of their volumes at 575 C°. Because of this fact is not appropriate to use in high fire risk buildings [2].
- Reactivity properties of aggregates can also cause beneficial or harmful effects on chemical reactions on microstructure of concrete. In this respect reaction occurred between the cement and quartz cause a strong bond. This event decays the thesis of weakening the bond occurred between cement paste and aggregate in each temperature increase. In fact, in some cases, heat gain, supports the formation of a positive effect of in the direction of strengthens of the chemical bond occurred between the cement and aggregate [7].

For example, in the study of the Koury and his team, after limestone and basalt being heated up to temperatures of 650 C0, they detect damages in the cooling stage as a result of the expansion. But the best results were obtained from experiments were used to fire bricks. Moreover, it's is obtained that in the studies of the last process of compressive strength of concrete obtained from the use of siliceous aggregates and cement replaced additives and uses after fire, is higher than only through the concrete made of Portland cement that have been identified. In addition, the temperature in the face of the strength of lightweight aggregate is lower than have been even identified. Due to these differences aggregate selection is great significance, particularly in the buildings of high fire risk for to minimize expansions as a result of expansions that may occur at high temperatures and structural damages may be occurred as a result of those expansions. In this type of building quartz has an important role on the use of siliceous aggregate and in the development of fire behavior of concrete.

3.1.2. Cement Paste (Çimento Pastası)

Cement paste, is an unstable component of concrete which undergoes basic physical and chemical changes during the first heating steps and for this reason in this process it has a considerably the role over reduction in strength. After cooling phase the cement paste tries to take moisture from the environment. Therefore, moisture value included in the phase of cooling after the environment has great importance in terms of use of concrete after heating phase. Building structure must be protected not only in fire period also be protected after fire. It should be also aimed to prevent the collapse of structure under a specific load because of reduction in strength over time. Otherwise a disaster may be encountered during using period of the building which is no occurring at the moment of the fire. For this reason aggregate and cement selection should be made carefully with composition rates obtained from experiments of fire under constant load. In this issue, behavior of cement should be eliminate at certain temperatures and value of cement composition should be created to appease the negatives occur in this values. Therefore, changes that occur in certain temperature in the cement structure are specified [7].

3.1.2.1. Behavior of the Concrete of Portland Cement against Temperature (Portland Çimentolu Betonun Sıcaklık Karşısındaki Davranışı)

To develop concrete behavior against fire, should be known which behavior exhibits and at which temperature value by pore portland cement. Different temperature changes that occur within the cement and concrete is specified below:

- **80-100C°:** There is not a significant change occur in concrete structure until 80C°. But at temperatures above 80-100C° water begin to lose that have been absorbed by the concrete. Hydrated cement particles will again react in the case of temperature rise above 100C° during fire. This event will cause a visible increase in concrete strength. With the temperature increase the water evaporates into water vapor in concrete and pore pressure occurs because of this event.
- **100-300C°:** If pore pressure created in cement paste at above 100C°, hydrothermal reactions rate and tensile forces which occurrences in microstructure could be affected. Byproducts occurred at the end of chemical reactions in concretes microstructure, fills the gaps occurred between cement and aggregate. In following reaction, pressure stresses increases on the inner surface of concrete. Water vapor occurs in case of temperature rise, increases the cavity pressure and causes throwing pieces of concrete surface. It should be accepted to be as a policy to design concrete, consist of minimum stress in microstructure which used in fire-resistant compartments. Studies of hardened concrete pore pressure that heated up to 350C° is measured at a value as high as 26N/mm^2. Obtained this value is higher than the tensile strength value of most hardened concrete. No doubt, this high value is also cannot resist to explosion and fragmentation of concrete. In this step, other binders having hydraulic properties which are used with replacing with cement is needed in concrete composition, to ensure increasing strength of concrete at high temperatures to resistance against explosion and fragmentations of concrete that the high temperature will cause [7].
- **300-600C°:** Increment is observed in pores and micro-cracks in the structure of cement paste at 300C°. Cracking starts at around crystals of calcium hydroxide and continues at around un-hydrated cement particles. These cracks can be seen with a microscope so that they are defined as micro-cracks. When the temperature reach 300C°, an increase will be observe in the crack size. At these temperatures especially large cracks appear between aggregate and cement matrix. Concretes volume expands after dehydration In the result of decomposition of

CaO. Because of this fact cracks occurred in the heated concrete expands after cooling phase. However cement paste containing fly ash, reduces the formation of cracks in the cooling stage reaction through calcium hydroxide reaction. [14]. If non-hydrated cement particles and calcium hydroxide crystals have higher rate, it can cause to continue the formation of micro-cracks at above 300C°. At about 400C°, Calcium hydroxide, in the hardened cement paste, begins to decompose and cause increment of stress and pressure consist of micro-structure of concrete. For this, reducing alternative cement compounds which decrease the amount of calcium hydroxide and un-hydrated cement particles, play an effective role in the development of performance at over 300C°. It is known that an ideal mixture of portland cement in concrete come up against a sudden decrease in the strength at 300-350C°. This is in accordance, with the actual tests at high temperatures; increase the use of portland cement and silica aggregate, against falling on the strength at 350C°. Another important physical change which begins at this temperature value is the color changes of the structure. The color of concrete turns pink then red [2].

- **600–700C°:** In Cement paste, at high temperatures, thermal effects, especially forms over 600 cause serious problems. While concrete cracks doubled at between 165-500C°, the rate of fracture increases up to ten times from the initial state when temperatures rise up to 600 to 670C°. Acceptance of this, it is come in view that critical limit values of microstructure of concrete at 550–600 C°, doesn’t constitute a great importance in terms of heat resistance. However, it can be seen that most of the concrete have less strength values at lower temperatures. Therefore, by the works that will be done for concretes these deficiencies, alternative solutions must be produced and concrete volume must be designed to resist explosions consist on concrete surfaces, at temperature degrees over 600C° during the fire. When rise up to 700C° it can be also observed that cement starts to lose all its binder property [7]. At these temperature degrees if look at physical changes on concrete surfaces, we can observe that chance of color from gray to beige until 1000C° and return to yellow after 1000C°.

3.1.2.1.1. Cooling Stage and Self-Repair of Concrete (Betonun Kendi Kendini Onarması ve Soğutma Aşaması)

This phase is the stage of self-repair of concrete in the presence of moisture. After cooling down phase cement paste regain moisture from the environment. Benefits and losses in tensile strength are defined as hunger of concrete to humidity after cooling. After cooling in the presence of moisture, cement paste subject to deterioration when CaO (lime) of concrete re-hydrate and expands. It is found that cracks have been filled by the time, though the byproducts that occur at the end of chemical reactions in the presence of moisture. But this event can be realized at the end of a very long time periods [11].

Positive and negative features that have been gained concrete, by Portland cement and puzzolan additives which are used replacement of fly ash and silica fume with binders, varies in each temperature. At temperatures above 600C° in concrete deep cracks and surface explosions occur because this fact 600C° must be considered as the upper limit temperature. It must be aimed to take this upper limit to higher temperatures, with the use of puzzolan additives and Portland cement together, in concrete used in fire compartments and places having high fire risk. For this, it must be determined that at which temperature degrees how result can be achieved using what proportions is required by the use of both of Portland cement and other additives.

After examining last experiments and studies have been done in this topic, it is listed below that how the behavior exhibited at which temperature degrees that binders and additives used to increase the heat resistance of concrete with portland cement and puzzolan blended concrete, at high temperatures.

3.1.2.2 Behavior of Concrete Filled with Puzzolan Additives against Temperature (Puzzolan Katkılı Betonların Sıcaklık Karşısındaki Davranışı)

Efforts have been made for concrete been exposed to high temperatures since 1920. But of research's about concrete's durability properties containing fly ash which was heated up to high degrees, have begun to be made into the last 10 years. The decrease in compressive strength of concrete varies with the additives added to the mixture. There are many reasons that affect this situation. These are shown below:

- Heating temperature,
- The highest degree,
- Dehydration of C-H and S jells,
- Thermally stability forms between aggregate and cement past.

Therefore additives used for improve the behavior of concrete in the face of increasing temperature must be chosen to develop these properties. For this reason, for obtain the best performance it is necessary to know at which temperature how they response. The works related about these issues have been given below [12].

- **100-300C°:** Puzzolan blended concretes have higher performance than normal concrete with Portland cement when heated up to 300 C° concrete. An increase is observed in the strength of concrete with puzzolan blended between 100-300 C^0. The highest resistance was obtained in the concrete containing silica aggregate [11]. Nasser and Marzouk heated up concrete containing fly ash replace with cement at a rate of 25%, to 323C° from 21.5 C° and they have observed changes during 6 mounts. The first of resistance was increased more than 52% between 121 C^0 and 149 C°. But between 177-232C° a decrease was observed in the strength and elasticity properties. In 1996, Ghosh and Nasser in their work, they added ash 10% silica fume next to 20-60% fly ash and they detected a significant reduction in compressive strength when heated to 232C°. They also found physical changes have been started under 70 C° and chemical changes have been started over 232 C°. Grainger searched behavior of samples including 20%, 25%, 37.5% and 50% of fly ash at 100-600C°. Especially he observed the improvements of reduction in exposition effects in temperatures over 300C°. Concrete containing 10% low-calcium showed similar characteristics with concrete with normal portland cement between 100-750C°, without considering whether aggregate used in concrete have silica or not [11]. Ghosh and Nasser performed tests on values of compressive strength and elasticity modules of concretes continuing 20-60% fly ash with 10% silica fume and high percentage value of lignite at high-temperature. At the end of these experiments between 21-232C° minimum compressive strength was obtained from the series used 20% fly ash. But the lowest compressive strength value obtained was 60% more than normal concrete. Grainger made same experiments by using blast furnace slag with the amount of 0-50-70%. He obtained the best performance from the series consisting of 70% blast furnace slag between at 100-250C°. And as a result of heating of this series, they have been measured the value of the compressive strength, 190% more than normal concrete. Sullivan and Shashar who were study on series containing silica fume and blast furnace slag and as aggregate, lightweight aggregate and the broken refractory bricks, applied compressive strength tests at above 150 C0. They obtained the best performance from the series containing broken fire-bricks and blast furnace slag.

- **300-600C°:** Concrete's having low permeability and porosity and containing high rates of silica fume, were found explosions and explosive spallings. Therefore, silica fume used with replace with cement should not exceed the weight of more than 15%. Also observed in these studies, each additive used with replacing doesn't give positive result in every situation, against fire. When exceeding the temperature of 300C°, the structure of concrete becomes very fragile and small changes are observed on the comprehensive strength. But a reduction is observed over 300C° in strength of concrete containing silica aggregate, limestone and fly ash [11]. Silica fume fills all the gaps in concrete with adhesive features of microstctures. As a result, with increasing temperature, dehydration products cannot find a place to settle down and over 350 C° explosive spalling can be seen in the concrete. In his works Hertz saw that concrete with silica fume at a rate of 14-20% exploded when they were heated up to 650 C°. It have been seen that when silica fume don't exceed 10% and used with the same proportions with granite aggregate, in the case heated up to 600C°, integrity of concrete can be protected. But at 600 C0, these concretes compressive strength are lower than Portland cement concrete [11]. Sashar and Khoury had tests on concrete containing fly ash heated up to 650C°. At the end of these experiments, they have seen 88% increase of compressive strength of fly ash concrete at 450 C°, and also 73% increases at 650C°. Cracks occur on concrete surfaces when volume expansion becomes as results of dehydration of $Ca\ (OH)_2$, after heating and cooling phase. It is seen that because of $Ca\ (OH)_2$ reduction in concretes containing fly ash, ratio of formation in cracks becomes less. 400C° is a critical point for cracks observed in Portland cement concrete [10]. After heating concrete containing fly ash up to 600C°, a great increase observed in values of compressive strength than normal concrete. And they have found superficial cracks in the cooling phase of this concrete. Especially these concretes have higher performance than silica fume blended concrete [11]. Khoury and Sashar were applied similar experiments with 65% blast furnace slag and 30% fly ash until heated up to 700C°. They obtained the best performance from the series prepared with 65% blast furnace slags, between 450-600C°. This value is 102%-80% greater than normal series for compressive strength.

- **600-700C°:** In concrete containing limestone and fly ash at 600C^0 and over temperatures, strength falls to half. When temperature reaches to 750 C0, at a rate of 75-93% reductions is observed in the strength of concrete. This reduction is seen mostly in concrete formed with limestone [12].
- **600-700C°:** Cracks behavior, occurred at high temperatures, and should be known even better to develop the behavior of concrete against fire. When they occur, how they affect to the deterioration of concrete, as a result of how mechanical or thermal stress they occur and what kind of a force to be effective in the formation are the elements which need to be investigated. After 1000C° 20 mm deep cracks occurs [8]. In Koury and his team's work contain the findings of chemical bonds that broken down at above 600-700 C°. In these experiments in case of replacement of ceramic binding with cement, the values in stress increase was observed until 800C°. After the first heating, ceramic binder replace with hydraulic binders are used in concretes with aluminum and heat-resistant because of high melting point [7]. In addition Poon has found high fire resistant of concrete with 30% and 40% blast furnace slag at 800C°.

3.1.2.2.1. Concretes with Propropilen Fibers (Propropilen Lifli Beton)

Nishida worked about fragmentation strength of concrete with polypropylene fiber at high temperatures. In these experiments, while Deep cracks and explosive spallings observed in pure concrete at high temperatures, partial cracks were being observed concrete in polypropylene fibers however there isn't explosive spallings observed in these concretes. General hypothesis in these studies is melting polypropylene fibers at above 170C° as a result of these forming small gaps inside the concrete. In observations made with Microscope, prevention of explosive spalling has been determined with meeting water vapor pressure with this pore [10].

4. DISCUSSION RECOMMENDATIONS AND EVALUATIONS (DEĞERLENDİRME-TARTIŞMA VE ÖNERİLER)

Works done to have better performance from concrete during fire still don't give the desired results. A sudden decrease in concrete strength is known at after about 300C°. But there aren't any available possibilities to develop the performance of concrete at high temperatures. But it is possible to increase the use of concrete at above 600 C0. With the hydraulic properties of Portland cement's and with more qualified binders that can be replaced by cement. But when go to above 600C°, because of explosions on the concrete surface's, we can see that integrity of the volume of concrete can be provide at lower temperatures. To have high performance of concrete we have to aim to minimize the decrease in comprehensive strength. Therefore, global solution must be proposed including environmental and material properties, they reveal underlying these mechanisms and acceptance that ensures the integrity of concrete throughout the whole temperature cycle. To form high performance concrete agaist fire, preferably concrete components have to perform high fire resistant.

- **Water/Cement Ratio (Su/Çimento Oranı):** To have the best yield, on hydrothermal circumstances under 300C° and cooling phase that occur after the event of too warming phase, the concrete mix preparation is preferred which obtain low water / cement ratio and calcium hydroxide composition.

- **Aggregate (Agrega):** Being stable of aggregate used in mixture from the thermal perspective, allows the formation of aggregate-cement bond that will provide resistance against high temperatures. Wet aggregates increased vapor pressure and causes spallings. So that dry aggregates should be selected. Using low density aggregates as quartz, perlite, slag, pumice-stone and sandstone increases the fire resistant of concrete. Also, limestone and basalt raise the fire resistance up to 650C°. Concrete with silica having normal weight, concrete containing carbonate and concrete with arduaz aggregates have fire resistance at 1000C°. Because of the fact that using concreate with carbonate and arduaz aggregates in places which have explosive chemicals, increases the the fire resistance of the structure.
- **Cement (Çimento):** The maximum temperature value of concrete feasible structural performance that can be providing during a fire because of portland cement properties is 600 C0. This tempreture degree can be rise up with the uses of fly ash and furnace slag replaced with cement. Also, cements containing magnesium absorb so much water that they have high performance against fire. Fire resistance of concrete increases over 600 C0 has been identified. When the work carried out examined, puzzolans of fly ash and slag concrete which used with replaced with cement at certain proportions. But, because of being spalled from surfaces of silica fume concretes over 350 C0, it is not appropriate to use this concretes in high fires risk. But Concretes used with 40% and 30% blast furnace slag have high fire resistance at 800 C°. Fly ash used with cement significantly reduces the risk of 'explosive spalling process under 300 C°. In addition, because of reducing the amount $Ca(OH)_2$, at least formation of cracks level downloads. Moreover Pores created by melting of propropilen fibers which effected by temperature Form spaces to expand for dehydration products, certainly prevent explosive spalling of concrete. Thermal conductivity value in lightweight concrete is 30-40% less than other concrete. Therefore, this concretes fire behavior is greater than the normal concrete.
- **Concrete Cover (Beton Kaplama):** Another principle to be taken into consideration about creation of high fire risk places is to delay the flow of steel which is inside concrete with influence of temperature. For this, according to fire risk of places that will be used, cover should be increased so that the protection of the reinforcement should be provided. While 1 cm of concrete that cover the reinforcement obtains the temperate reach up to 600C°, stells temperature will reach 350C°, when 3cm of concrete covers the reinforcement Therefore, such places covers must be at least 4cm.

5. RESULTS (SONUÇ)

It must be provided to the duration of the structure in reinforced concrete structures of high fire risk, in evacuation period during fire and it must be used after having small repairs without losing its carrier capacity. Selecting the appropriate concrete composition influence the service life of reinforced concrete structure after fire and damage and life losses that may occur during a fire. Especially fire resistance of the concrete has a great importance used at high temperature places like factories, laboratories, ect. and high explosion risk places. Also, places having high fire load and fire temperature rise rapidly and laboratories and warehouses that contain flammable chemical gases or liquids, must be maintained a safe environment during evacuation and extinguishing period. But this case can be accomplished only by selection of fire retardant concrete materials and using such additivities to improve the fire resistant of concrete with concrete components. In line with this study, examining the reaction to fire of concrete components, it is determined that how much additional strength can concrete gain against rising temperatures by puzzolan additivites. For this, protection of integrity of concrete can be achieved with the help of fly ash and blast furnace slag additives added into the cement and with the use of quartz, perlite, basalt, and siliceous and carbonate aggregate up to 1000C° and higher temperatures. The material which has high density absorbs heat too much, stores and transmits so concretes having low-density have fire resistance to the higher degrees. With Furnace slag and fly ash and without silica fume which reacts with free lime inside of concrete, will develop in the direction of behavior of comprehensive strength and durability characteristics at high temperatures. Besides this concretes added with polypropylene fibers not created fractures even at high temperatures so it is recommended to use in the creation of high fire risk places and fire compartment.

REFERENCES (KAYNAKLAR)

1. Grainger, B.N., (1980). Concrete at High Temperatures. Central Electricity Research Laboratories, UK.
2. Çelebi, M.R. ve Akıncıtürk, N., (2003). Yangın. İstanbul Kültür Üniversitesi Yayınları, İstanbul.
3. Ghosh, S. and Nasser K.W., (1996). Effects of High Temperature and Pressure on Strength and Elasticity of Lignite Fly Ash and Silica Fume. Concrete Materials Journal: 1(93)401-50. DOI: 10.14359/9795.
4. Harper, C.A., (2004). Handbook of Building Materials for Fire Protection. McGraw- Hill.
5. Hertz, K.D., (1992). İnvestigations on Silica Fume Concretes at Elavated Tempetures. ACI: 4(89), 345-347, DOI:10.14359/9750.
6. Hertz, K.D., (1984). Heat İnduced Explosion of Dence Concretes. İnstute of Building Design. Technical University of Denmark. Report no: 166.
7. Khoury, G.A., (1992). Design of Concrete for Beter Performance in Fire. C438/042.
8. Kordina, K., Wydra, W., and Ehm, C., (1992). Analysis of the Developing Damage of Concrete due to Heating and Cooling, Materials and design Against Fire. Proceedings of İnstitution of Mechanical Engineers. Bridge Walk London.
9. Nasser, K.W. and Marzouk, H.M., (1979). Properties of Mass Concrete Containing Flasy Ash at High Tempetures. ACI Mater. J.: 4(76), 537-551, DOI: 10.14359/6958.
10. Noumowe, A., Carre, H., Daoud, A., and Toutanji, H., (2006). High-Strength Self-Compacting Concrete Exposed to Fire Test. Journal of Materials in Civil Engineering: 6(18), 754. DOI: 10.1061.
11. Poon, C., Azhar, S., Anson, M., and Wong, Y., (2001). "Strength and Durability Recovery of Fire-Damaged Concrete after Post Fire Curing", Cement and Concrete Composites, 31(130), 1318.
12. Sava, A., Manita, P., and Sideris, K.K., (2005). Influence of Elevated Temperatures on The Mechanical Properties of Blended

Cement Concretes Prepared with Limestone and Siliceous Aggregates. Cement and Concrete Composites: 2(27), 239-248.

13. Sullivan, P.J.E. and Sharshar, R., (1992). Performance of Concrete at Elevated Temperatures: Fire Technology: 3(28), 2009-2016, DOI: 10.1007/BF01857693.
14. Wong, Y.L., Xu, Poon C.S., and Anso, M., (2003). Influence of PFA on Cracing of Concrete and Cement Paste after Exposure to high Temperature. Cement and Concrete Research: 12(33), 1065-1073.
15. Xu, Y., Wong, Y.L., Poon, C.S., and Anson, M., (2001). Impact of High Temperature on PFA. Cement and Concrete Research: 7(31), 1065-1073.
16. Yu, X., Wong, Y.L., and Anson, M., (2000). Damage to PFA Concrete Subceted to high Tempetures. Prooceedings of İnternational Symposium on High Performance Concrete Workability, Strength and Durability, 1093-1100, Hong Kong.