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A Comparasion Study of Impact of Fire on Steel Reinforcement of R.C.C Structures

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ABSTRACT:

With the rise in significant building fires, the assessment, repair, and rehabilitation of fire-damaged structures has become a hot topic. This is a highly specialised discipline that requires knowledge on this topics, including concrete technology, material science and testing, structural engineering, and repair materials and processes, among others. This, as well as other related areas, are the subject of research and development. The experience of real-life problems is described in this topic, which adds a great deal of value to it. This topic also provides overall strategy for the restoration of fire-damaged structures, as well as a critical review of the assessment procedures using various non-destructive techniques, specifications, and repair methodologies.

The influence of fire on reinforcement steel bars was investigated by heating the bars to temperatures of 100°, 300°, 600°, and 900° centigrade for six samples each. The heated samples are quickly cooled by quenching in water and, in most cases, by chilling in the air. A universal testing machine is used to investigate changes in mechanical characteristics, while a scanning electron microscope is used to investigate grain size and structure at a microscopic level (SEM).

The majority of fire-damaged RCC structures are repairable, according to the findings. When rapidly cooled by quenching, however, the influence of elevated temperature exceeding 900°C on the reinforcing bars was detected, with a considerable reduction in ductility. When chilled under air circumstances, the effect of temperature on ductility is minimal. The reinforcing bars can be modified without changing the chemical composition by heating them.

KEYWORDS: rehabilitation, non destructive techniques, universal testing machine, microscopic study, scanning electron microscope, ductility

INTODUCTION:

The assessment, repair, and rehabilitation of fire-damaged buildings has becoming hot topic as the number of significant has increased. Concrete technology, material research and testing, repairing materials and techniques, and other areas of competence are all part of this specialist subject. In these linked domains, research and development efforts are underway. Any structure can be destroyed by fire, yet the structure cannot be denied or abandoned as a result. The community facing challenges in restoring a structure's functionality after it has been damaged by fire. The issue is determining where to begin and how to proceed. It is critical that we construct buildings and structures that provide the best possible protection for both persons and property. Annual data on fire-related losses in homes and elsewhere make for depressing reading, and tragically, it is through these tragedies that we learn more about fire-safety design.

Building design and use, structural performance, fire extinguishing measures, and evacuation procedures all influence the magnitude of such damage. Although fire safety standards are written with this express purpose, it is understandably the safety of people that assumes the greater importance. Appropriate design and choice of materials is crucial in ensuring fire safe construction According to a survey of 16 industrialised nations (13 in Europe plus the United States, Canada, and Japan), the number of people killed by flames in a normal year was 1 to 2 per 100,000 people, and the total cost of fire damage was 0.2 percent to 0.3 percent of GNP. According to figures compiled by the National Fire Protection Association (USA) for the year 2000, fire caused over 4,000 deaths, over 100,000 injuries, and more than $10 billion in property damaging in U.S.. According to UK data, roughly a third of the half million fires attended by firefighters each year occur in occupied houses, resulting approx. 600 fatalities. Each year, fires cost millions of pounds in lost revenue. Fire safety codes and regulations are changed on a regular basis, usually in research and development area.

Pietro Croce et al. present a novel approach for measuring damage in R.C.C. structures. Wei Lin et al investigated the microstructure of fire-damaged concrete using SEM and a stereo microscope for concrete heated to 900°C to obtain visual information that would otherwise be impossible to see with the naked eye, which will aid in understanding the behaviour of concrete in firing. R. Folic et al gave a case study of firing buildings structure. Chi-Sun Poon et al described the strengthening and durabilities recovered of fire-damaged concrete after post-fire drying in 2001Sir William Halcrow & Partners Ltd's M. A. Riley presented a paper on a possible new method for assessing fire-damaged concrete. N. R. Short et al. investigated the use of picture analysis to assess fire-damaged concrete. A. Y Nassif et al of Londan University investigated the effects of quick cooling by qualities of fire-damaged concrete in 1999.

EXPERIENCE OF FIRES:

Fire damaged slab

CHANGES OF CONCRETE IN FIRE:

Concrete structure doesn't catch fire — it cannot be'set on fire' like other building materials, and doesn't generate poisonous chemicals when burned. It does not release smoke, other plastics and metals. For that reasons, concrete having higher fire resistance, and it can be categorised as "fireproof". It shows this just because of ingredients content of concrete, which, when chemically mixed within concrete, produce a material that is virtually inert and, crucially for fire safety design, has a low heat conductivity. Concrete can operate as a fire shield not just b/w adjacent spaces, but protecting itself from fire damage, thanks to its slow rate of heat transfer (conductivity). Because the rate of temperature increase along the cross section of a concrete is slow, internal zones doesn't reaching the same higher temperatures as flame-exposed surface. An ISO 834/BS 476 fire test on 160 mm wide x 300 mm deep concrete beams after one hour of exposure on three sides revealed that, while a temperature of 600°C is reached at 16 mm from the surface, this value drops to just 300°C at 42 mm from the surface, a 300°C temperature gradient in about an inch of concrete! Concrete's internal temperature remains relatively low even after a lengthy period of time, allowing it to preserve structural capacity and fire-shielding capabilities as a separating element.

LITERATURE REVIEW:

George Faller of Arup Fire, has recommended the performance based approach. Based on the time equivalent notion, a public presentation-based technique for estimating fire resistance needs. A mapping of fire load, compartment linings, and ventilation conditions is the comparable calculation. The firefighting period is estimated flame, structural failure, and the impacts of an automatic suppression system.

David N. Bilow et al. present review of the complex behaviour of structures under firing, and simplified procedures that have been successfully used to withstand the effects of serious flames. Following the September 11th trade Center, interest in the construction of fire-resistant social institutions skyrocketed.

S. C. Chakrabarti et al. An thorough trial plan determine the residual efficacy of concrete when the intensity level was increased to 500°C, and it was discovered that after roughly a year, it regained 90% of its lost strength up to this temperature.

Yaqub et al. and Haddad et al. ferrocement, a cementitious substance made from of wire meshes and mortar, was used to repairing fire-damaged buildings. Although ferrocement is labor-intensive to apply, the craftsmanship required to build it is relatively modest, are readily available locally. Using ferrocement to repair structures is inexpensive and excellent for residential constructions in underdeveloped nations like Malaysia.

Gillie et al. analysed the effects of travelling fires in the behaviour of a steel beam, concluding that a wide range of strains and stresses are recorded in the beam depending on RC Frames Exposed to Fire 18 type of fire input, obtaining remarkably different results when compared against the beam's response subjected to a uniform fire. Because of the travelling nature of the fire, a complex interaction between tensile and compression forces is observed in the beam as heating and cooling are occurring simultaneously in different parts of it.

Franssen et al. also investigated the effect of localized fires in the structural response, implementing the necessary modifications in the code SAFIR to enable it to deal with this type of fire models. The modification performed in is also suitable to fire analysis when the fire action is given by a CFD model.

Taillefer et al. using the code SAFIR, investigated the differences obtained regarding RCC beams and 2D frames when exposed to different fire models, identifying the necessity of carefully couple thermal and mechanical models in order to obtain sound results.

Rein et al. developed a procedure to account for the non-uniformity of the fire within the compartment avoiding the complexities of CFD models. The procedure consists of dividing the compartment into a near field zone comprising the part of the compartment directly exposed to the flame, and a far field zone comprising the rest of the compartment. Figure 2.2 sketches the concept of far-near field.

Bailey et al. presented a procedure to account for compartment firing scope of natural fire curves. That procedure consists of assuming an initial scenario of compartments in fire, and when the temperature in these compartments reaches its peak value, the fire curve is applied to the adjacent compartments.

Khoury et al. strain model for unsealed and loaded concrete during first heating (the most frequent conditions of structural concrete exposed to fire) is composed of the sum of the following term.

Khoury et al. these terms have been separated for the first time and the thermal strain is related to the thermal expansion of non-drying concrete. Besides the academic models referred, there is also the stress-strain model prescribed in the EN1992

Law et al. have studied the implications for structural analysis of LITS. In this study the ATM model, the Khoury's (numerically modelled by Terro) model and de EN 1992 1-2's model have been examined and the results compared. It has been concluded in this study that the correct choice of E is critical to the accuracy of the results. As the implementation of the two academic models above referred involves the creation of a stress-strain curve varying with temperature and then modified by the consideration of the transient effects, it has shown to be important to carefully analyse the results considering the actual and the apparent (derived from the initial gradient of stress-strain curve) modulus of elasticity.

Gillie et al. refers that the consideration of biaxial compression in concrete allows the improvement of its strength approximately to 10 % of the uniaxial value.

Schneider et al. proposed model for c/c in compression at temperatures incorporating elastic, plastic and creep strains as function of temperature and load history, aiming to complete the existing EN 1992 1-2's model. With this model one is able to consider the effect of thermal creep and load-history in all phases of thermal exposure. The different parts of deformation are approximated with discrete equations interacting in concrete model. And its capable for realistic behaviour of concrete structures, even during fire cooling. Considering the load-history during heating up to obtain an increasing load-bearing capacity due to high stiffness.

Schneider et al also states that, because this model considers the thermal-physical behaviour of material laws, it will lead to a better evaluation of the safety level when applied to EN 1992 1-2 calculation system.

Schneider et al. performed an application of the material model presented in (referred as advanced transient concrete model) to the analysis of tunnel cross-section subjected to fire. And its compared against the ones obtained with the EN 1992 1-2 constitutive curve. It was concluded that the EN 1992 1-2 curve does not allow the determination of realistic values of structural deformations when compared to the results obtained with the proposed model (which according to Schneider et al. is based on measured data). It proposed model should be applied if an optimization of concrete is desirable.

Sadaoui et al. investigated the effect of transient creep on the behaviour of reinforced concrete columns in fire. it has been learned that transient creep induces additional compressive stresses, magnifying bending moment, thus leading to anticipated structural failure. An important drawback in the knowledge of concrete properties when exposing to firing is the lack of understanding of its behaviour during cooling.

Dwaikat et al. when analysing a beam exposed to parametric fire simply considered cooling stage concrete does not recover any of its properties loss in the heating process. The mechanisms experimented by the concrete mix during cooling have been analysed by Khoury.

Klingsch et al. during the cooling stage in supersulfated slag cement concrete tends to confirm the trends described by the EN 1994 1-2 model for decay phase. These results have shown a clearly nonlinear material behaviour of concrete when cooling down.

Luccioni et al. It based on a plastic-damage model extended to consider temperature induced damage. In this model the thermal damage through a damage variable that is a measure of the deterioration due to temperature. The concept of irreversibility of damage is presented in this model meaning that the thermal damage variable is irreversible. The application examples of the model have demonstrated this formulation capable of simulating the residual mechanical behaviour of concrete, characterized by the stiffness and strength loss.

Dwaikat et al. proposed a macroscopic finite element model for the analysis of RCC, where spalling is considered by means of a simplified hydrothermal model through the calculation of pore pressure. This hydrothermal model is based on thermodynamics principle including liquid water and water vapour to predict pore pressure, and the mass transfer of water.

Deeny et al. investigated the influence of spalling in the structural analysis of concrete exposed to fire. During this investigation, it was assumed that the occurrence of spalling was certain, i.e., all conditions capable of inducing spalling are considered to be fulfilled. In the study it was analysed when spalling would happen based essentially in the heating rate of concrete.

Venazi et al. performed a global fire analysis regarding a set of two-bay RCC frames of two and three storeys. The bays span was considered to be 6.0m or 8.0m in order to investigate the effect of different stiffness relations between the beams and the columns. The results obtained in displayed a significant redistribution and increase of internal forces with respect to those for which the frame had been designed, underlining the important role played by global behaviour during the structural response to fire action.

Huang et al. analysed the behaviour of RCC to fire including the behaviour of floor slabs. The results obtained illustrate that slabs behaviour during fire exposure is highly influenced by both tension and compressive membrane action.

Kothai et al Steel slag, a waste affordable material used as F.A. in M20 grade concrete, is discussed in this paper, and it is suggested that the material be approved for use as F.A. replacement material in concrete. Strengthening, modulus of elasticity, can be increased by up to 30% by partially replacing natural particles in concrete.

Iyyappan et al When strengthening was compared to regular concrete after 28 days of curing, it increased by 6.34 percent and 8.68 percent, respectively, lathe metal scrap into concrete by 2% and 3%. However, if the concrete contains more than 4% lathe metal debris, compressive strength is reduced by 7.21 percent.

Shankar Meena Rashmi Sakalle Nitin Tiwari (2018); In their investigation, they used 10%, 20%, 30%, 40%, and 50% substitution of F.A. utilising stone dust or steel powder, which were examined at different curing durations of 7th days, 14th days, and 28th days. They identified an experimental concrete study that used dust and steel powder as a half-replacement for sand. When compared to typical concrete mix, flexural strength was enhanced by 9.23 percent and 10.38 percent, respectively, after 28 days. It can be stated that stone dust and steel powder can be used in concrete mix because of the high strength values reported at 39 percent replacement in strength parameters.

Zainb Hashim Abbas Alsalami (2017); Using varied amounts of pistachio shells as a half-substitute for sand, the effect of using pistachio shells as a half-substitute for sand on the properties of cement mortar was examined (10, 20, 30, 40, 50, or 60 percent by wt. of F.A.). The effects of cement mortar density, absorption, and compressive strength were studied as well. The cement used was ordinary Portland cement. Compressive strength of mortar cubes was evaluated at 7th , 14th , and 28th days at various percentage replacement levels, providing values of 6.78, 8.92, and 14.1 MPa, respectively, at 20 percent replacement.

B. Pujitha N. Swathi Sk. Jain Saheb (2017) It represent concrete to see how unwanted plastic or shredded rubber affects the concrete. They used grade 53 Portland cement, graded C.A., sand, superplasticizer, pozzollanic material, plastic waste, waste tyre rubbers, and water. They cast cubes out of M30 concrete, which were subsequently tested using a compression testing machine. Materials substitution percentages of 0 percent, 5 percent, 10 percent, 15 percent, and 20 percent are utilised for cube casting. On the 7th, 14th, and 28th days, strength was at a very low level, according to test findings. It indicates that when 20% of the material is replaced, M30 grade concrete cannot resist good strength. The strength rapidly deteriorated as the percentage of replacement increased. Baskaran.P,Karthickkumar.M,Krishnamoorthy.N,Saravanan.P,HematNaveen(20 17) A research on M25 grade concrete with half substitution of F.A. by GGBS at various percents of 0%, 5%, 10%, and 15%. The specimens were cast for seven, fourteen, or twenty-eight days before being tested. The maximum flexural strength achieved by 15% half-substituting F.A. with GGBS is found to be higher than that of standard concrete. This study, strength was acquired extremely well on the 7th, 14th, and 28th days. According to the data, high strength values were discovered at 15% GGBS replacement.

K. Karthika, G. Snekha, R Sinduja, S Priyadharshini (2017); Experiments have been conducted on the use of quarry dust and metallic dust in the production of concrete. They were made out of M20 concrete with varied quantities of fine aggregate, including 0%, 20%, 30%, 40%, and 50% quarry dust and 2% metallic dust. N.Sreeivasulu, A.Roopa, M.Venkateswarlu, P.Pavani (2016) have identified an experiment on concrete that uses sand as half substitution material. Copper slag concrete was created at various levels (0, 20, and 40%) and subjected to a variety of tests. The findings reveal that raising the copper slag replacement level improved strengthening and breaking tensile strength of mixes, and that using copper slag as a half substitute for sand is cost effective. Ananthayya M.B Prema Kumar W. P., Vijay K(2014); To test compressive strength of concrete, IOT (iron ore tailing) and GGBFS were substitute by (iron ore tailing) and cement by granulated blast furnace slag. The researchers discovered that increasing IOT and GGBFS replacement levels boosted strengthening. Replacement of sand is cost-effective up to 60%, and the IOT, Its essentially compressed without sacrificing strength, may be used effectively.

Bahoria B.V,Parbat D.K,Naganaik P.B.(2013); have discovered that waste products discarded tyres, plastic, glass, burnt foundry sand, Coal Combustion By-Products may replace natural sand, and have conducted numerous tests compressive strengthening, splitting tensile strengthening, and concluded dust replaced up to 40% of the sand, while Crushed Granite Fine (CGF) can be used to replace up to 20% of the sand. Crushed Granite Fine containing up to 20% crushed granite Spent Fire Bricks (SFB) can be used up to 25% of the time, while crushed rock flour can be used up to 40% of the time without impacting strength or workability.

Dr. K. Srinivasu, M. L. N Krishna Sai, N. Venkata Kumar Concrete is largely used building material, which depletes natural resources, causing environmental concerns in terms of raw material use and CO2 emissions during cement production. As The heat of hydration is reduced when cement is replaced with pozzolana. Fly ash, base ash, blast furnace slag are common industrial waste materials. Concrete is interested in elective cementation products such as metakaolin, silica fume, steel fibres, quarry dust, wood waste, limestone, and calcined clays. Heat of 6000°C to 8000°C causes dehydroxylation of crystalline structure of kaolinite, resulting in metakaolin. Kaolinitic clay is commonly available in the earth crust. At 10% condensate silica fume, 5% MK, and 1.5 percent steel fibre material, high tensile strength was observed. Blend, control concrete concrete with 8% MK and 1.5 percent steel fibre has an improving compressive strengthening 8.9%, tensile strength of 26.94 percent, flexural strengthening of 58.28 percent. The uses of metakaolin in concrete as a 25% substitute for cement resulted in excellent strength and durability improvements. It has improved water permeability and absorption, results in increasing in concrete density. Metakaolin was used in the preparation of acid resistance concrete, which showed strong resulting in provisos of chloride permeability and sulphate resistance.

Pragada Rambabu This mix's lime concrete, which has a higher degree of versatility than standard concrete, was obtained as strong base for load-bearing walls, columns, and lying under floors. This is unique waterproofing property which protect subsoil dampness in floors and walls.. Lime concrete can also be made simple and inexpensive while also offering a durablility of material which having resistance weathering and wear and tear. For M20 grade concrete, the substitution of cement by lime powder is performed in 10 percent increments from 0% to 30% in order to maintain a steady slump of 60mm. At room temperature, strengthening of cubes age of 7 or 28 days is measured in 28th days and split tensile strengthening of concrete was measured. The overall both strengthening was only gained at 30 percent replacement. These mixtures, used as 30% substitute for Natural River sand, exhibit greater strength than control concrete.

Tarun R Naik and F.ASCE It was determined that replacing 15% to 20% of opc clinker with limestone filler with a Blain fineness value of 4000 to 4500 cm2/gm satisfying strengthening of ordinary in the early hours strengthening of 32.5 Mpa.

Hongjian Du and Kiang HweeTan Shows that a 60% replacement reduces the water penetration depth upto 80% when keeping the compressive power at 85%. Glass powder as F.A. providing greater resistivity to chloride penetration in concrete, and max. heat evolution rate or total heat produced both decrease with increasing OPC substitution levels. because of the dilution of cement and GP's slower pozzolanic reaction The period to achieve the peak hydration rate is shortened in occurrence of GP,. As a result, water resistance, and chloride penetration were observed.

R. Vandhiyan, K. Ramkumar and R. Ramya It was discovered that the cost of concrete, and utilization of cement, has decreased, resulting in a direct reduction in CO2 emissions, which is linked to progress of surface area of finer glass particles; however, its rises water demand. By comparing the strengthening gain to cement mortar, it could deduced that 15% glass powder substitution, there is a strength increase. The benefits of this project include the use of cement instead of glass powder. This also lowers the cost of producing concrete. When substitution % raised upto 10% and above, it showed a slightly rising water demand. This must be accredited to fact that it is a low-cost concrete that is still high-quality. It is possible that the uses of unwanted glass to replace cement would decrease.

Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen Steel slag as aggregate for stone mastic asphalt was the subject of research. According to their findings, the test roads perform well later 2 years of use, with an abrasion and friction coefficient of 55 BPN and a surface texture depth of 0.8 mm.

Aly et al (2011) Differential thermal analysis and thermo gravimetric analysis (TGA) were used to investigate heat of hydration in cement compounds, which revealed a significant increasing compressive strengthening of cement paste made with Nano clay and waste glass crystal powder as compared to Portland cement..

Liu et al (2015) X-ray diffraction, thermos gravimetric, DTA used for investigate the influence of curative temperature on the features of unwanted glass powder in cement-based substances. Final conclusion of this tests indicate that a high curative temperature promotes the pozzolanic response of glass powder. Which improving mechanical or overall performance of the microstructure The pozzolanic reaction in glass powder particles.

Jang et al (2017), which looked at the borosilicate G.P. to improve thermal neutron shielding capacity. The TG- DTA curve for a 28-day cement paste with 20% borosilicate glass powder revealed a DTA curve at roughly 430– 470 °C, which was accompanied by significant weight loss (TG curve) at this time. As G.P. increased, the thermal neutron shielding performance increased. As a result, it used as a mineral stabiliser for a variety of radiation shielding applications.

Chiou et al (2013), The degree of glassiness and smoothness of sediment, and alkali-silica reactivity and chemical- corrosion resistance of reservoir-sediment aggregates aggregate surfaces, are all increased as WG fineness increases. The addition of a waste glass which having size less than 150 m has a beneficial effect on sediment.

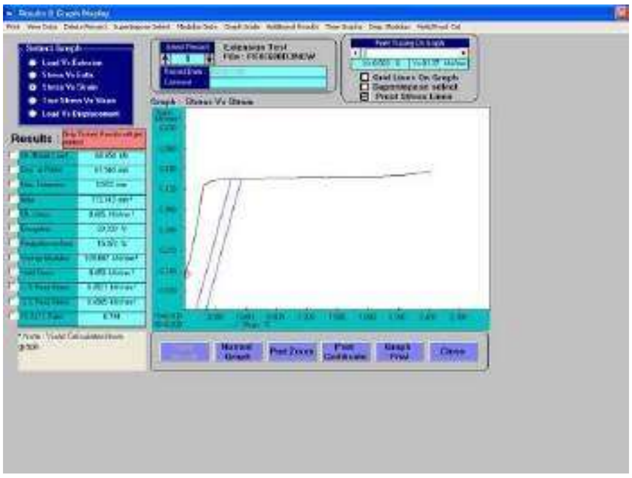
Nwaubani et al (2013), The characteristics of concrete mixed with unwanted glass as opc in % as 5%, 20%, and 30% were analysed. The unwanted glass material used into acquire completely from green glass cullet floor to a fineness of 300 µm. The results earned display indeed that glass powder complements the compressive strength characteristics of the very last concreting creation if used on the proper level of the substitute. Earth and Environmental Science 357 (2019) 012023 IOP Publishing doi:10.1088/1755-1315/357/1/012023 5 of alternative plus the size and distribution of glass particles appear to be of crucial significance for the advantage of pozzolanic interest to come to be evident in the short-term.

Penacho et al (2014), studied the uses of mortar with a cement-to-sand a vol. proportion of 1 to 4 were formed % of sand replace by fine glass aggregates, while the aggregate's size distribution in the replacement remained the same. The outcome illustrate that the mixture of 20% substitute of sand and fine glass aggregates could be used for interior and inside the building or in the façades.

UTM TESTING

The 12mm steel bar is cut to 40 cm length and 60mm gauge length. The specimen is fixed on machine and data on the computer is given. Test is conducted at a load rate of 300 kg/min for all the specimens. An extensometer is fixed during the test to read the elongation. The data is noted in computer during the test by default s it is setup. The graph of load versus deformation and load versus elongation is drawn on the computer. Other metrics that can be seen after the test include ultimate load, maximum extension in mm, area in mm2, ultimate stress, elongation in percent, reduction in area, young's modulus, yield stress,.1 percent and.2 percent proff stress, and many others.

UTM TESTING SETUP



TENSILE TEST USING UTM RESULT SCREENSHOT

TENSILE TESTING

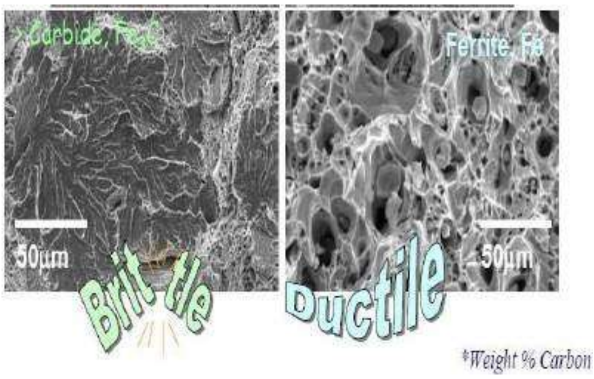
Tensile testing is done according to ASTM D-638 and ISO 527, which is a combined tensile and flexural technique. The most important single indicator of a material's strength is its tensile characteristics. Force required to separate the specimen is calculated, as well as how far the material may stretch before breaking. The tensile modulus is the stress-to-strain ratio lower than the material's proportional limit. This is the most valuable tensile data because parts should withstand to stresses much below this value.

SEM

JSM- 6480LV was used to perform scanning electron microscopy at magnifications of 5µ x5000 and 10 µ x1000 x1000. The specimens have a diameter of 12mm and a length of 10mm. For a clear view of the gain size and grain structure, the specimens must be carefully polished in all edges and cleanly cleaned with acetone before testing.

SETUP OF SEM

INTERNAL IMAGE OF SEM



SEM PROPERTIES OF STEEL BAR

ELECTRIC FURNACE

The specimens are heated in an electric furnace. This furnace can reach a maximum temperature of 1000°C. The furnace has a 45mm inner depth. Initially, the furnace is heated to the required temperature by turning it on, and after that temperature is reached, six specimens are placed inside with the doo snugly closed to prevent air from entering. The specimens are held inside the furnace for an hour, after which three are quenched in water for quick cooling and the other three are set aside for atmospheric time. After 15 minutes, the three water-quenched specimens are removed. 6 bars are kept at 100°C, 300°C, 600°C, and 900°C each time, and the process is repeated.

CONCLUSION

1. The effect of fire on reinforcement bars heated to temperatures of 100° C, 300° C, 600° C, and 900° C, quenched in water quickly, and typically cooled at ambient temperature, was studied. and it was discovered that the ductility of rapidly cooled bars after heating to high temperatures of 900 ° C was significantly reduced.
2. Studying the characteristic changes in property of bars by Tensile strength testing using Universal Testing Machine shows that the increase in ultimate load and decrease in % elongation which mean that there is significant decrease in ductility of the specimen.
3. An examination of the microstructure by SEM reveals that the microstructure of highly heated specimens fluctuates without a change in chemical composition, which would have a negative impact on the structure.

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