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FOAM STEEL JACKETS FOR STEEL COLUMNS

Sports stadiums, skyscrapers and airport terminals – structures of this size must meet higher-than-normal levels of fire safety. Especially if they have a steel frame that could rapidly lose its stability in a catastrophic event. VINNAPAS® EZ 3112 is a new binder from WACKER that helps to boost the heat resistance of such structures.

WWW 1.13 ▸ SPECIAL ▸ FIRE PROTECTION

Come 2014, when Brazil hosts the World Cup Finals and then the Olympic Games in 2016, entire nations will be glued to their screens. They will see tens of thousands of fans flocking to gigantic, futuristic stadiums where sporting rivalries will be fought out against a striking backdrop of steel frames and steel roofs designed to convey an impression of lightness and airiness. Steel frames have a low dead load, but a high load-bearing capacity. They are supplied prefabricated and are bolted together quickly and easily on site. This makes steel constructions statically ideal as skeletal structures for exhibition halls and airport terminals.

It's a construction method that is especially popular for office tower blocks in the booming cities of the Far East. But wherever people congregate in large numbers, safety aspects must play an equally "weighty" role alongside structural efficiency and esthetics.

EVER MORE INTRICATE ARCHITECTURE

"Architecture is becoming increasingly more intricate and delicate. At the same time, buildings still need to meet all specified safety standards," says Dr. Wilfried Huster, former head of Application Technology for Dispersions in Europe at WACKER POLYMERS. This applies especially to those relating to fire. True, the steel columns themselves are not flammable, but this otherwise highly stable material has an Achilles heel – intense heat. When the temperature reaches 500 °C, steel frames soften rapidly, and the buildings are in danger of collapse. "Basically, the steel just 'floats' away," says Dr. Niels Friede, process engineer and head of Emergency Services/Fire Safety at WACKER in Burghausen. Not only that, steel expands extensively in heat. "Unlike stone and even wooden walls, which undergo little dimensional change, steel columns lengthen and widen. In so doing, they force other components apart, thereby further weakening the structural stability," adds Friede.

Symphony of steel and glass: state-of-the-art shopping center in Warsaw, Poland.

GREATER RESISTANCE

That is why fire safety is so crucial in steel-frame structures. One solution here is to boost the resistance of the columns by painting them with so-called intumescent coatings, which swell in the event of a fire and confer greater "staying power" to the metal columns. The coatings are applied like paints in thicknesses ranging from just 300 micrometers to several millimeters, the precise thickness depending on the application. Even though these heat shields are fairly thin, they nonetheless afford substantial protection. "When a fire breaks out, the coating swells by 10 to 100 times their original thickness to form a thermally insulating foam jacket around the steel column," says Huster. The thermal insulation properties stem from the foam's high density and very fine pores. The foam slows the rate at which the steel heats up, greatly delaying the time taken to reach the critical 500 °C. "The buildings can thus resist a fire for much longer, and that gives the rescue teams more precious time to save lives," adds Friede, a fire expert.

If the intumescent coatings are to generate the insulating foam in a fire, certain ingredients are essential. Alongside "reactive" components such as melamine, pentaerythritol and ammonium polyphosphate (such as Clariant's Exolit® AP), they contain organic binders made by WACKER. "The binder in a fire safety coating must do more than simply hold the filler particles together, like it does in conventional wall paint. It has a much wider range of tasks to do," stresses Huster.

When the temperature reaches 250 °C, the binder fuses to form a matrix in which subsequent thermochemical reactions can take place. The first reaction is decomposition of the ammonium polyphosphate, which constitutes one quarter of the intumescent coating and is the largest ingredient. This reacts with the pentaerythritol ingredient to form phosphoric acid esters. If the temperature keeps rising, the esters themselves start to decompose, forming ester residues that contain carbon and phosphorus. Meanwhile the melamine also decomposes, emitting ammonia and nitrogen gases. These act as a blowing agent that gradually expands the carbon and phosphorus ester residues into a layer of insulating foam.

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500 °C is a critical point at which steel structures begin to lose stability. Intumescent coatings help to greatly delay the time taken to reach this point.

TURBULENCE AND VIBRATIONS

"Extensive studies have shown that special copolymers based on vinyl acetate and ethylene – in other words, our VAE dispersions – and terpolymers are particularly effective in promoting the formation of a stable matrix," explains Huster. Without the binder, the insulating effect of the thermal shield would be extremely difficult to achieve because the shield would be too brittle and would not adhere securely enough to the metal substrate. "Fires are usually accompanied by severe air turbulence and vibrations. It is essential then that the foam layers do not spall away," says Achim Hennemann, key account manager for Intumescent Coatings at Clariant, a chemical company that produces the ammonium polyphosphate (Exolit®) that constitutes the main component of fire protection coatings.

Although the binder plays a supporting role in intumescent coatings, it is nonetheless crucial to their efficacy because it determines how fast the layer of foam forms and its thickness around the steel columns. This consideration meant that, as they were developing their new dispersions specifically for such applications, the experts from WACKER POLYMERS needed to work closely with their colleagues from Clariant. The new VINNAPAS® EZ 3112 dispersion generates foam in much a greater yield and with an even finer, denser pore structure. A corollary of this greater efficiency is that a lower overall coating thickness is required than in conventional systems, without sacrificing any insulating effect. Thus, thanks to the new binder, fewer coats are needed.

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Dr. Wilfried Huster, former technical service head of Dispersions and Resins at WACKER POLYMERS, in a meeting with Stefanie Werkstetter at the application technology lab's storage area.

FIRE PROTECTION COATING IN A LABORATORY TEST AT CLARIANT

As of a temperature of 200-250 °C, ammonium polyphosphate begins to decompose and reacts with the pentaerythritol to form phosphoric acid esters. At higher temperatures, the melamine content decomposes – generating gaseous ammonia and oxygen which expand the carbon- and phosphorus-containing residues of the esters. In just a few minutes, a multi-cm-thick insulating layer is formed with a thickness several hundred times that of the original coating.

"Intumescent coatings often need seven coats – and just as many drying periods," explains Clariant manager Hennemann. "So, thinner coats that deliver the same performance, i.e. fire resistance time, will save on material, time – and costs."

PROTECTION VIA VOLUME

In VINNAPAS® EZ 3112, the WACKER experts have also managed to comply with the increasingly stringent sustainability requirements – the new binder does not contain plasticizers and is produced without alkylphenol ethoxylate-containing materials. A further plus for the environment is that the dispersion is not based on organic solvents but is water-borne. "And the market for water-borne fire protection coatings could grow significantly in the next several years," estimates Hennemann.

Not only in the event of fire must a binder fulfill its purpose. Coatings firms usually store fire protection coatings for long periods. "The viscosity must not change during the period in storage, i.e. the product must remain stable," stresses WACKER expert Huster. "Thanks to our new binder, products will remain stable even when stored at elevated ambient temperatures."

Nearly all countries specify that steel structures – whether they be all-glass, see-through exhibition halls or towering office blocks – must satisfy certain criteria governing the length of time they have to be able to resist fire. In Germany, "F 30" means that a load-bearing steel structure must be able to withstand a fire, i.e. heat, for at least 30 minutes under standard conditions. "The thinner the steel cross-section, the thicker the fireproof coating must be to achieve the required fire rating. Nowadays, intumescent formulations are capable of achieving an F rating of two hours and longer," says Clariant's Hennemann.

VINNAPAS® EZ 3112 is just one example of WACKER helping to ensure that steel structures withstand fires for precious extra minutes that could save lives. ■

Thanks to prefabricated parts and bolted joints, steel frames can be assembled quickly and easily – thereby providing ideal construction of storage depots, for example.

Figure 1: steel column without intumescent coating

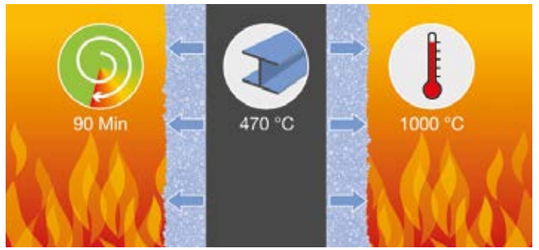

Figure 2: steel column with intumescent coating

FIRE TEST ON STEEL

A steel column without an intumescent coating (figure 1) assumes the temperature of its surroundings in just a few minutes and rapidly loses structural stability above a temperature of 500 °C. If, however, the steel column is protected by an intumescent coating (figure 2), which expands in a fire to protect the metal, the steel column reaches the critical temperature of around 500 °C much later, depending on the coating's fire protection class – in this example some 90 minutes. Up until then, it maintains its stability.

Dr. Klaus Bender heads Application Technology for Intumescent Coatings at Clariant AG.

“A MATRIX TO GENERATE FOAM”

Fire protection buys time – and that saves lives, says Dr. Klaus Bender, head of Technical Marketing, Intumescent Coatings, at Clariant.

Why do steel structures need their own specific fire-safety precautions?
Extremely high temperatures are generated in a fire. And though the metal itself will not burn, if it is left unprotected, steel columns can soften and collapse in 10 to 20 minutes, depending on the intensity of the fire and the thickness of the columns. To give the fire department enough time to complete evacuation, such buildings need particularly good fire protection. Intumescent coatings are ideal at protecting steel structures against the effect of heat, because in a fire they swell to as much as 100 times their original thickness, repelling the heat. The dense foam formed has a stable carbon backbone, and under heat exposure its components react, compacting even further.

How do you test ingredients for suitability in fire protection coatings?
At our labs in Hürth-Knapsack, we apply intumescent coatings to small steel plates and then expose them to heat. We have special furnaces there that enable us to simulate fire scenarios and replicate various fire profiles in compliance with DIN 4102 Part 8. These furnaces can reach 800 °C in 35 minutes, for example. The foam layers are black at first, but the color gradually fades as the heat rises, until eventually they turn virtually snow-white. Rather like when charred wood turns to ash.

What are the key ingredients of intumescent coatings?
At some 20 to 30 percent, depending on the formulation, the main component is ammonium polyphosphate (APP), which Clariant produces in Germany under the Exolit® AP trademark. Basically, the foam heat shield consists of the decomposition products produced by this substance and another chemical that serves as a carbon donor. The quality of the binder is key to intumescent coatings, though. It determines the success or failure of a good recipe because the binder generates the matrix in which the foam, in turn, will be generated.

How do the the protective foam layers function in the event of a fire?
Their most important job is to keep the surface temperature of the steel as low as possible. By doing so, they extend the time that is available to rescue workers. Depending on the building's fire rating – which varies widely from country to country – a steel column must hold out for a minimum 30, 60, 90 or 120 minutes before it reaches the critical temperature. That's a precious time window for evacuating people. In hospitals, airports, shopping malls and sports stadiums, and wherever people congregate in large numbers, more time to fight the fire translates to more lives saved. It is also important for the fire protection coatings themselves to have a long service life and stay fully functional for many years and even decades. Load-bearing parts are therefore inspected regularly to ensure the coating is intact. If it has been damaged, the affected area is simply sanded down and recoated.

EXPERTISE AND SERVICE NETWORK ON FIVE CONTINENTS

• Sales offices and production sites, plus 18 technical centers, ensure you a local presence worldwide.

WACKER is one of the world’s leading and most research-intensive chemical companies, with total sales of €4.6 billion. Products range from silicones, binders and polymer additives for diverse industrial sectors to bioengineered pharmaceutical actives and hyperpure silicon for semiconductor and solar applications. As a technology leader focusing on sustainability, WACKER promotes products and ideas that offer a high value-added potential to ensure that current and future generations enjoy a better quality of life based on energy efficiency and protection of the climate and environment.

Spanning the globe with 4 business divisions, we offer our customers highly-specialized products and comprehensive service via 23 production sites, 18 technical competence centers, 13 WACKER ACADEMY training centers and 48 sales offices in Europe, North and South America, and Asia – including a presence in China. With a workforce of some 13,450, we see ourselves as a reliable innovation partner that develops trailblazing solutions for, and in collaboration with, our customers. We also help them boost their own success. Our technical centers employ local specialists who assist customers worldwide in the development of products tailored to regional demands, supporting them during every stage of their complex production processes, if required. WACKER e-solutions are online services provided via our customer portal and as integrated process solutions. Our customers and business partners thus benefit from comprehensive information and reliable service to enable projects and orders to be handled fast, reliably and highly efficiently. Visit us anywhere, anytime around the world at: **www.wacker.com**

All figures are based on fiscal 2016.

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