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Experimental study of the performance of intumescent coatings exposed to standard and non-standard fire conditions

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Abstract
Three different experimental setups corresponding to three different fire scenarios were used to investigate how different heating conditions and heating rates affect the behaviour of two different thin intumescent coatings (a solvent-based and a water-based paint). Coated steel samples were exposed to different standard and non-standard fire conditions in an electric oven, in a gas furnace and in a cone heater. A general trend was observed in the thermal resistance development for the tested intumescent coatings, divided into three general phases: inert phase, transient phase and steady phase. The different stages were identified according to four critical points: activation, end of reaction, binder exhaustion and steel austenitization point. The tested water-based paint had better performance for low heating rates, while the tested solvent-based paint had better performance for high heating rates. However, for really low heating rates the solvent-based paint did not activate or provide proper insulation. In summary, the results confirm that the current procedure for the design of intumescent coatings has shortcomings, as different paints have different performances according to the heating conditions and, in particular, according to the fire heating rate.

[…]

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References
[1] J. Dowling, Fire protection costs for structural steelwork, New Steel Construction, United Kingdom, 2003.
[2] G.Q. Li, G.B. Lou, C. Zhang, L.L. Wang, Y.C. Wang, Assess the fire resistance of intumescent coatings by equivalent constant thermal resistance, Fire Technology, vol. 48, pp. 529-546, 2012.
[3] L. Wang, Y. Dong, D. Zhan, C. Zhang, Experimental study of heat transfer in intumescent coatings exposed to non-standard furnace curves, Fire Technology, vol. 51, no. 1, pp. 627-643, 2015.

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[4] International Organization for Standardization (ISO), ISO834-1, Fire resistance tests - Elements of building construction - Part 1: General requirements for fire resistance testing, Geneva, Switzerland, 1999.
[5] Comité Europeén de Normalization (CEN), EN 13381-8, Test methods for determining the contribution to the fire resistance of structural members - Part 8: Applied reactive protection to steel members, Brussels, Belgium, 2013.
[6] Y. Zhang, Y.C. Wang, C.G. Bailey, A.P. Taylor, Global modelling of fire protection performances of an intumescent coating under different furnace fire conditions, Journal of Fire Science, vol. 31, no. 1, pp. 51-72, 2012.
[7] M. Bartholomai, R. Schriever, B. Schartel, Influence of external heat flux and coating thickness on the thermal insulation properties of two different intumescent coatings using cone calorimeter and numerical analysis, Journal of Fire Materials, vol. 27, pp. 151-162, 2003.
[8] B.K. Cirpici, Y.C. Wang, B. Rogers, Assessment of the thermal conductivity of intumescent coatings in fire, Fire Safety Journal, vol. 81, pp. 74-84, 2016.
[9] C.E. Anderson, D.E. Ketchum, B. Schartel, Thermal conductivity of intumescent chars, Journal of Fire Science, vol. 16, pp. 390-410, 1988.
[10] G.Q. Li, J. Han, G.B. Lou, Y.C. Wang, Predicting intumescent coating protected steel temperature in fire using constant thermal conductivity, Thin-Walled Structures, vol. 98, pp. 177-184, 2016.
[11] A. Elliott, A. Temple, C. Maluk, L. Bisby, Novel testing to study the performance of intumescent coatings under non-standard heating regimes, Fire Safety Science – Proceedings of the Eleventh International Symposium, pp. 652-665, 2014.
[12] J. Kolšek, P. Cesarek, Performance-based fire modelling of intumescent painted steel structures and comparison to EC3, Journal of Constructional Steel Research, vol. 104, pp. 91-103, 2015.
[13] A. Lucherini, Experimental study of the behaviour of steel structures protected by different intumescent coatings and exposed to various fire scenarios, M.Sc. thesis, Department of Civil Engineering, Technical University of Denmark (DTU), 2016.
[14] International Organization for Standardization (ISO), ISO 5660-1: International Standard, Fire tests - Reaction to fire - Part 1: Rate of heat release from building products (Cone Calorimeter Method), Geneva, Switzerland, 1993.
[15] European Committee for Standardization (CEN), Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design, EN 1993-1-2, 2005.
[16] A. Bilotta, D. de Silva, E. Nigro, Tests on intumescent paints for fire protection of existing steel structures, Construction and Building Materials, vol. 121, pp. 410-422, 2016.
[17] J.H. Andersen, Experimental study of the thermal resistance of intumescent coatings exposed to different heating rates, M.Sc. thesis, Department of Civil Engineering, Technical University of Denmark (DTU), 2015.
[18] R. Reed-Hill, R. Abbaschian, Physical metallurgy principles, PWS-Kent Publishing, 3rd edition, Boston, 1991.
[19] R.I. Costa, “Thermal resistance of steel profile protected with intumescent coatings”, M.Sc. thesis, Department of Civil Engineering, Technical University of Denmark (DTU), 2016.