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PRINCIPLE SCHEMA OF AN ORIGINAL FULL-, AND REDUCED-SCALE TESTING BENCH, DESTINED TO FIRE PROTECTION INVESTIGATIONS

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Abstract: The authors present the principia of an original testing bench, destined to evaluate the fire-resistance behaviours of the full-scale, as well as the reduced-scale structural elements, subjected to different fire scenarios. The presented scheme is conceived for the column-type elements, but it can be extended also to other ones. The twelve Silite-type electric-heated elements are electronic-controlled and assure a desired stable thermal regime (up to 800^{0}C) with $\pm 1.5^0$C accuracy. The requested power supply is a 380 AC, with a minimum 30 A permissible current intensity. The presented testing bench can substitute successfully in the above-mentioned testing conditions the relatively difficult and also unsafe gas-burners systems. In the authors opinion this new principia will become useful in the thorough fire-protection experimental investigations, both for unprotected as well as for the protected structural elements.
Keywords: testing bench; electric-heating; electronic-control; fire-protection; full-scale & reduced-scale structural elements

1. INTRODUCTION

It is a well-known fact, that the structural analysis in fire protection by means of full-scale elements presents several draw-backs in comparison with the reduced-scale models' testing.

In this sense, one can mention among others:

- high manufacturing and experimental costs;
- great time-consuming both in the manufacturing and in the performed tests;
- great difficulties concerning in assuring proper rooms or space for the experiments;
- numerous high-qualified persons, which have to be involved in these processes (manufacturing, experiments, etc.).

This is the reason why several researches accept the reduced-scale models' analysis both by means of theoretical (numerical or/and analytical) and experimental ways.

In this sense, the Dimensional Analysis offers the most suitable information set for a pertinent comparative analysis between the full-scale and reduced-scale structural elements' fire-resistance responses. By means of the obtained dimensionless sets, one can find suitable correlations between the reduced-scale model and the full-scaled prototype.

One can mention that every dimensionless parameter contains fixed correlation between several thermal and geometrical parameters of the full-scaled and reduced-scale model. By performing a few numbers of experimental investigations (even on reduced-scale or full-scaled model), one will obtain a fixed value for the analysed dimensionless parameter, i.e. a strong correlation between the involved thermal or/and geometrical parameters, contained in this dimensionless parameter.

Consequently, by means of changing (one by one) one of the involved thermal or geometrical parameters, e.g. for the reduced-scale model, it becomes possible to predict the corresponding magnitude for the full-scaled ones, or vice versa. This represents one of the main advantages of the Dimensional Analysis. Another one consists in time-saving and cost-reducing of the foreseen experiments.

This is the reason, why numerous scientists have a great interest in the applying of the Dimensional Analysis in the fire-protection and fire-resistance problems. Between others, the contribution of Quintiere [2] can be mentioned, where several useful dimensionless parameters of the Dimensional Analysis, applied to the fire propagation and fire protection problems are presented.

In the reference [1] there are described comparative numerical modelling in ANSYS-Fluent code, concerning on two fire scenarios of full-scaled and reduced-scaled models, based on the dimensionless parameters proposed by Quintiere [2].

The authors of [8] describe their theoretical and experimental investigations on thermo-protected full-, and reduced-scale models, based on the Dimensional Analysis, including the significant influences of the insulation materials properties as well as their thickness magnitudes.

The authors of the references [3; 7; 9; 10] describe their theoretical and experimental investigations results in the fire resistance problem, based on the applications of the Dimensional Analysis.

The general approach of the Dimensional Analysis is described in an original manner by Szirtes in reference [11]. Other interesting and useful applications of the mentioned approach are described in the references [4; 5; 6]. Of course, only a few numbers of the useful results obtained by the scientists in the field of fire protection and fire resistance were mentioned here.

2. TESTING BENCH PRESENTATION

The authors, taking into consideration the above-mentioned advantages of the Dimensional Analysis, conceived an original testing bench, which assures high-accuracy comparative experimental analysis on full-, and reduced-scale structural elements. Its principle schema is presented in Figure 1, having the following main components: on the high-stiffened support 1 the special heat-insulated box 2 is fixed. In the upper part it presents a given opening 7, where the heat amount produced by means of the twelve Silite-rods 5, supplied by three-phase AC 6, will be taken over by the tested structural element 8.

One can mention that the electronic control system of the heating elements 5 assures a desired stable thermal regime (up to 800^{0}C) with ±1.5^{0}C accuracy. In this sense, the requested power supply has to be a 380 AC, with a minimum 30 A permissible current intensity.

The principle of the thermal analogy from point of view of the Dimensional Analysis, is stated in the reference [11] by Szirtes, i.e.: "two bodies are thermally similar if in their homologous points, or surfaces, they have equal or homologous temperatures at homologous times; in other words, two bodies can be considered thermally similar if their heat-flow patterns are similar".

Taking this principle into consideration, the authors had foreseen the heating box with the above-mentioned windows 7.

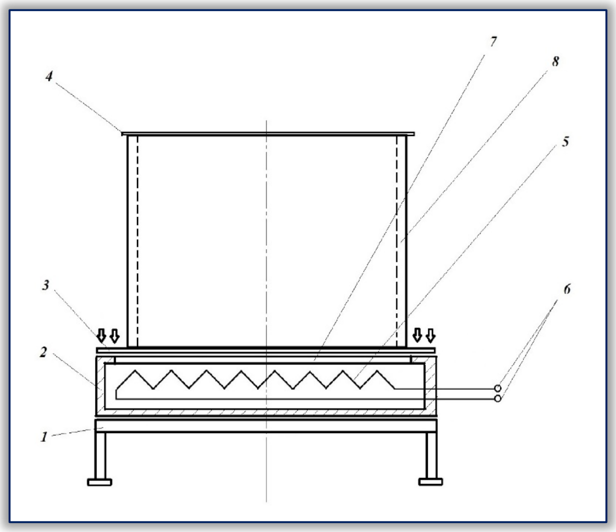

Figure 1. The principle schema of the testing bench

Every tested structural element 8 (in this case: column-type one) will present the same dimensions for their lower-end plate 3, in order to assure the same heat-flux for them. Of course, depending on their real cross-sectional dimensions, each of them will take over different percentages from the given heat-flux.

In order to assure as much as possible a precise amount of the overtaken heat flux, every tested structural elements' lower-end plate 3 will be insulated near their junction with the above-mentioned structural element (this zone is marked with double arrow in Figure 1). In this way, even unprotected or protected structural elements are tested, so the uncontrolled heat loss will be practically integrally diminished.

Oppositely, the upper-end plate 4 will not be insulated in any of the cases (even unprotected or protected structural elements are analysed). So it will simulate the convection of the heat flux to the remaining upper part of the structural element, which isn't included in the tested element.

In order to perform a high-accuracy thermal calculus, the testing bench s foreseen with an adequate electronic device, able to monitor the invested electrical power during the test.

The heat-insulation of the box 2 prevent practically any heat-loosing and consequently one can state that it is assured an integral transformation of the invested electrical power

$$E = U \cdot I \cdot t \ [W \cdot s] \tag{1}$$

into heat $Q[J \, or \, W \cdot s]$, which is transferred 100% to tested structural element (the tested bar).Thus became possible to establish the magnitude of the introduced heat amount Q at the lover end of the tested structural element.

In relation (1) $U[V]$ represents the monitored electric voltage; $I[A]$ - The current's intensity and $t[s]$ - The monitored time.

One has to mention that the tested structural element is foreseen with numerous thermocouples, which monitor along its whole length the real temperature distribution $t(z)\left[{}^0C\right]$, where $z\left[mm\right]$ represents the coordinate of one thermocouple, measured form the heated (lower) end of the tested bar.

In the reference [12], Turzó describe the differential equation of the temperature distribution law in a massive cross-sectional straight bar with its general solution

$$t(z)=c_1\cdot e^{m\cdot z}+c_2\cdot e^{-m\cdot z}+t_a\,, \tag{2}$$

where: $t(z)\left[{}^0C\right]$ represents the effective-measured temperature of the tested bar, heated at its lower end; $c_1\,,\,c_2\left[{}^0C\right]$ - Constants; $t_a\left[{}^0C\right]$ - The temperature of the environment/ambient near/beside of the bar; $m=\sqrt{\frac{P}{A}\cdot\frac{\alpha_n}{\lambda}}\left[\frac{1}{m}\right]$ - A general-accepted parameter; $\zeta=\frac{P}{A}\left[\frac{1}{m}\right]$ - The shape-factor of the bar, named also as massivity of the bar; $P\left[m\right]$ - The cross-section's circumference (perimeter) of the tested bar; $A\left[m^2\right]$ - The cross-section's area of the bar; $\alpha_n\left[\frac{W}{m^2\cdot K}\,\text{or}\,\frac{W}{m^2\cdot{}^0C}\right]$ - The heat transfer coefficient of the bar's napple; $\lambda\left[\frac{W}{m\cdot K}\,\text{or}\,\frac{W}{m\cdot{}^0C}\right]$ - The thermal conductivity coefficient of the bar's material.

How was demonstrated in [11], in the case of the massive cross-sectional bars, the hypothesis of $m=const.$ and also this relation (2) are valid for the whole length of the tested bar.

Oppositely, in the case of the tubular cross-sectional bars, how was proved by the authors in their previous experimental investigations [12], both the hypothesis of $m=const.$ and the relation (2) remain valid only for some shorter intervals, not for the whole length of the bar. In this case, minimum three intervals can be putted in evidence, having different magnitudes of the parameter m and of course, different corresponding thermal distribution laws.

Afterward, based on the experimental-obtained thermal distribution laws, without reference to the mentioned cross-sectional cases, one can determine by calculus the involved thermal parameters in the steady thermal equilibrium of the tested structural element (here: column-type one).

In this sense, first one has to establish the magnitudes of the parameter m for different intervals of the tested structural element. Using its value, between others, became possible to obtain by calculi the most significant parameters along the whole length of the bar, e.g.: the heat transfer coefficient α_n of the bar's napple, as well as the thermal conductivity coefficient λ of the bar's material, which, for an accurate calculus, have to be considered dependents from the coordinate z.

The authors consider that by successively testing the full-, and reduced-scale structural elements it becomes possible to establish useful correlations between the thermal and geometrical parameters as well as to validate several dimensionless parameters, established theoretically by means of the Dimensional Analysis.

3. CONCLUSIONS AND FURTHER GOALS

— the authors described the principia schema of a new testing bench, destined to full-, and reduced-scale structural elements' analysis;

— the testing bench is electrical-heated and electronic-controlled, offering a high-accuracy thermal stability for the tested structural element;

— it will assure both the validation of several, theoretical-obtained dimensionless parameters and the establishing of some new, useful correlations between the full-, and reduced-scaled structural elements;

— based on the testing bench particularities, it can be applied both for full-scaled and reduced-scaled elements analysis;

— taking the specific electronic control system into consideration, the described testing bench will be able to assure the real thermal similarity between the real (full-scaled) and reduced-scaled models, in order to perform thorough experimental investigations based on the Dimensional Analysis;

— the authors are convinced that this new testing bench type will become a useful instrument in the fire-testing applications.

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