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EFFECT OF THERMAL MASS ACTIVATION ON CONCRETE MECHANICAL PROPERTIES OF BUILDING STRUCTURES

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1. Introduction – Net Zero-Energy buildings (NZEBs) [1] collaborate to solve the constant concerns about energy supply constraints, decreasing energy resources, increasing energy costs and the rising impact of greenhouse gases on word climate. Thermo-active building systems [2], as low exergy systems, are defined as heating or cooling systems that allow the use of low valuated energy, which is delivered by sustainable energy sources, as geothermal energy, i.e., using building foundations as heat exchangers with the soil. (Figure 1)

The effect of thermal activation on the mechanical behaviour of these concrete building structures can be analysed on three levels, the effect on the ground [3], on the foundation [4], and on the structural slabs [5]. The impact of thermal loads on the mechanical response of the ground and on the behaviour of energy foundations has been studied, but thermo active slabs studies [6] already performed are focused in estimate the thermal comfort and energy consumption.

The aim of this work is to study the concrete behaviour of thermo-active slabs and foundations due to the inclusion of embedded pipes in which fluids circulate at low temperatures.

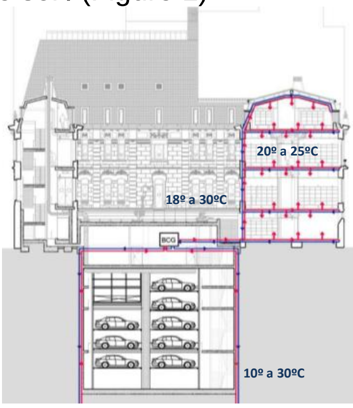

Figure 1 Thermo-active building system. ENERES

2. Methods – In order to assess the effects of an increase in temperature and its influence on the mechanical behaviour of concrete, compressive strengths and the anchoring resistance of steel bars in concrete were studied. 52 specimens made from two different types of concrete, H-25 and H-30, were produced and subjected to four different temperatures, 20ªC, 40ºC, 70ºC and 100ºC. Half of them were formed in cylindrical moulds 100 mm dia. and 200 mm height, and they were used to evaluate concrete compressive strength. The other 26 specimens were prepared in cubic moulds, 100 x 100 x 100 cm^3, with a 10 mm dia. central reinforcement to carry out pull-out test.

To evaluate the influence of the inclusion of pipes, a further 54 specimens were made from two different types of concrete, H-25 and H-30: 24 specimens were prepared in cylindrical moulds (Figure 2) and 30 in cubic moulds. These specimens with 24 mm dia. polyethylene pipes embedded at different positions were tested to compression.

Figure 2 Cylindrical specimens with 24 mm dia. Polyethylene pipes embedded in different positions tested to compressive strength.

3. Results and Discussion – In order to compare the results obtained in the tests from different points of view, the most representative values were selected and calculated from the data obtained in the compression tests, these are maximum strength σ_{max}, maximum strain ε_{max}, ultimate strain ε_u, maximum strain energy E_{max} and ultimate strain energy E_u. At the same time, values obtained from the pull-out tests were pull-out strength F_R, maximum displacement δ_{max}, ultimate displacement δ_u, maximum strain E_{max}, ultimate strain energy E_u.

The correlation between the strength loss, the temperature and the position of the pipes, for concrete H-25 and H-30, is shown in table 1. As can be seen, strength losses increase as temperature increases, both in the compression test and in the pull-out test, producing stress losses of around 20% when concrete H-25 reaches 70°C and concrete H-30 reaches100°C. In the pull-out test, the strength loss values are greater at lower temperature, reaching values above 20°C in the two types of concrete for 70°C temperature. The introduction of polyurethane pipes reduces concrete strength in both cylindrical and cubic specimens, with losses over 20% when the pipe is in a horizontal position, i.e. perpendicular to the load.

	Compression test	Pull-out test		Compression test	Compression test	
	Cylindrical	Cubic		Cylindrical	Cubic	
Temperature (ºC)	Strength loss (%)	Strength loss (%)	Concrete type	Strength loss (%)	Strength loss (%)	Pipe position
20	0,00	0,00	H-25	0,00	0,00	Pipeless
	0,00	0,00	H-30	0,00	0,00	
40	5,35	12,01	H-25	5,17	12,76	Vertical centered
	5,70	17,91	H-30	9,43	6,37	
70	19,05	24,15	H-25	13,45	------	Vertical decentered
	11,16	31,00	H-30	10,50	------	
100	24,40	37,37	H-25	21,27	23,33	Horizontal centered
	22,74	47,05	H-30	27,85	16,20	

Table 1 Strength loss in concretes H-25 and H-30, for different concrete temperatures and pipe position. (Losses exceeding 20% strength are marked)

3. Conclusions - The expected degradation in the temperature ranges in which these thermo-active building structures operate (as a high-temperature cooling system, 16-20ºC, and a low-temperature heating system, 25-30ºC) is very small regarding existing behaviour studies of concrete subjected to high temperatures [7], however it is necessary to quantify this degradation for their safe design.

From the results obtained in the test can be drawn that an increase in temperature diminishes its mechanical properties, regardless of the type of concrete, and the inclusion of polyethylene pipes embedded in concrete specimens reduces their mechanical properties, this reduction being more pronounced for a pipe laid perpendicular to the application of load. It can be concluded that thermo-active concrete structures perform best when the polyethylene pipes are placed parallel to the load and, regarding the temperature of fluids, it can be affirmed that the concrete mechanical properties are not jeopardized with strength losses of more than 20%, because the fluid temperature is always below 70ºC.

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