COMPARISON OF VULNERABILITY CONDITIONS OF ADOBES' STRUCTURE – THE STUDY OF HISTORICAL AND RESTORED ADOBES OF KOOH-E KHAJEH ANCIENT SITE (KOHAN DEZH CASTLE) IN SISTAN, IRAN

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Abstract: *Adobe constructions are very frequent in dry, hot and desert regions. Due to weather conditions and the availability of suitable resources and earth to make adobes, Kohan Dezh castle, at the foot of Kooh-e Khajeh hill (Sistan region) is among the first places where such constructions were made. Owing to the particular properties of the adobe, the constructions have always been vulnerable to weather conditions, especially moisture. Before restoring such monuments and altering their structure, sufficient research on their morphology and scientific-based restoration experiments need to be carried out; the results are integrated in planning the restoration project and the related scientific research. In Kohan Dezh Castle Restoration Workshop Project, restoration adobes produced in a previous restoration project were compared to the original adobes in order to understand the differences in their structure and constituent components. In the next stage, results were used to carry out necessary experiments to examine the vulnerability conditions for each of these samples against moisture. Finally, the strengths and weaknesses of restoration adobes were also studied. The analyses included gradation of the soil comprising the adobes, determination of density and porosity percentage, capillary tension test, water immersion test, abrasion resistance test, compressive strength test, and artificial rain which proved that the adobes produced for restoration were more vulnerable to moisture-induced damage then the historical ones. In order to optimize the structure of restoration adobes and increase their resistance against moisture-induced damage, their structure and gradation of their compounds and particles were modified so as to resemble those of the historical ones.*

Cuvinte cheie*: Chirpic, restaurare, castelul Kohan Dezh, vulnerabilitate, granulometrie, Kooh-e Khajeh, Sistan*
Rezumat*: Construcțiile din chirpici sunt foarte frecvente în zonele calde, aride și deșertice.Ca urmare a condițiilor climatice și a disponibilității materiei prime pentru realizarea chirpiciului, castelul Kohan Dezh, de la poalele dealului Kooh-e Khajeh (regiunea Sistan) este printre cele mai vechi construcții realizate din chirpici. Prin natura lor, construcțiile din chirpici sunt vulnerabile la condițiile de mediu, în principal la umiditate. Înainte de a restaura astfel de construcții și a le modifica structura trebuie cercetată morfologia acestora științific și experimental, iar rezultatele trebuie integrate proiectele de cercetare și restaurare. În cadrul Dezh Castle Restoration Workshop Project a fost analizat chirpici folosit la restaurarea castelului și apoi a fost comparat cu chirpiciul original, pentru a evidenția diferențele de structură și compoziție. Rezultatele au fost apoi folosite în experimente care investigau vulnerabilitatea acestora la umiditate. În final, au fost studiate punctele tari și cele slabe ale chirpiciului folosit la restaurare. Analizele au constat în studierea granulometriei, densității, porozității, tensiunii capilare, impactului la imersiunea în apă, rezistenței la abraziune, la compresie și la ploaie a chirpiciului folosit la restaurare; testele au demonstrat că acesta este mai vulnerabil la influența apei decât chirpiciul antic. Pentru optimizarea calității și rezistenței chirpiciului modern la apă se impune modificarea structurii și granulometriei acestuia astfel încât să fie cât mai asemănător cu cel antic.*

INTRODUCTION

Sistan is located in a vast territory in the southeastern Iran, a large part of it being today part of Afghanistan. The Sistan region, along with Baluchestan, make the Sistan and Baluchestan Province of Iran (see Moradi *et alii* 2013; 2014; Mutin 2017; Sarhaddi-Dadian 2015a; 2015b; 2017a; 2017b; 2020). Kooh-e Khajeh is the only elevated feature in the Sistan plains, located 30 kilometres away from the city of Zabol (See Fig. 1). The complex consists of Islamic and pre-Islamic structures, which are considered to be Iran's most prominent adobe monuments (Sarhaddi-Dadian 2013).

Adobe has been one of the oldest and most important construction materials used for building both houses and giant and stately structures, from the pre-historic period up to the present day. The monuments located at Kooh-e Khajeh in Sistan are unique adobe structures with special value. On this mountain are located special architectural structures, including Kohan Dezh Castle, Kok Kohzad Castle, Chehel Dokhtaran Castle and other scattered structures and tombstones. The most important of these structures is an imposing castle called by the locals Kohan Dezh. The extraordinary value of this