PHYSICAL PROPERTIES OF AN UNWEATHERED CO CHONDRITE FALL, MOSS.

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Introduction: Carbonaceous chondrite meteorites represent amongst the most primitive material of the Solar System. Understanding ther physical properties is needed to understand the evolution of the early Solar System and particularly the evolution of their parent bodies. For example, knowledge of physical and thermal properties of carbonaceous asteroids is required to quantify non-gravitational forces that perturb their orbits and rotation rates, and their response to impacts. Knowing the physical properties of carbonaceous meteorite lithologies is also helpful in designing spacecraft like OSIRIS-Rex, engineered to sample the surface of 101955 Bennu [e. g. 1].

Due to the rarity of samples of carbonaceous meteorites, just a few destructive measurements (such as strength) have been done compared to those for other types of meteorites. Our study consists of measuring physical properties of a CO meteorite, Moss, using both non-destructive and destructive methods. The Moss meteorite is a recent (and quickly recovered) fall (July 14, 2006) from Norway. Moss is a CO3.6 shock stage 2 that contains abundant small chondrules, olivine aggregates, troilite and kamacite in a gray matrix; it contains only 0.25% of carbon [2]. No previous destructive mechanical measurements have been done on a CO meteorite.

Methodology: Portions of an irregular interior Moss sample were cut into rectangular cuboid shapes using a diamond wire saw (Well, Model: 3032-4): to minimize sample contamination/modification all the cuts were done without the use of any fluid. A thin section billet was cut adjacent to the cuboids' volume. Cuboid dimensions were determined using a stainless steel digital micrometer. Porosity and grain density were measured using a gas (helium 99.9999%) pycnometer (Quantachrome Instruments, model: MVP-D160-E): The seismic waves velocity were measured using a pulse generator, oscilloscope (Tektronix Model DPO2014), two pairs of compressional and shear wave ultrasonic contact transducers (Olympus V133 and V156, respectively). Both the shear (Vs) and compressional wave velocities (Vp) were measured along three orthogonal directions. The compressive and shear strengths were measured with an electromechanical compression test machine (TestResource model 313 Q) using force transducer`s model SM-5000N-294 (TestResource).

Results: The mean bulk density and the grain density obtained for Moss are respectively 2.94 g/cm^3 and 3.71 g/cm^3. Moss has a porosity of 21.0 % ± 0.1 %. The Vp and Vs, mean values, are 2120 m/s and 1290 m/s respectvely: interestingly a seismic anisotropy exists in Moss that ranges, w.r.t. the average, from + 11.5% to – 9.8% in Vp, and from + 6.1 % to -5.8 % in Vs. This seismic anisotropy could be related to preferential orientation of some minerals or/and preferential orientation of the pores (still to be verified petrographically). We measured the compressive and shear strengths with the cuboids oriented along the fastest direction. The compressive strength ranged between 27.2 MPa and 27.8 MPa and the shear strength ranged between 8.3 MPa and 10.7MPa. The derived dynamic Young`s Modulus (E), Shear Modulus (μ), Bulk Modulus (K) and Poisson` ratio (υ) from the bulk density and the seismic velocities [3]; results are: $\upsilon = 0.21$, E = 11.8 GPa, $\mu = 4.89$ GPa and K = 6.72 GPa.

Discussion: The 31 MPa of tensile strength for Kainsaz (CO chondrite) reported by Svetsov et al. 1995, (only strength value ever reported for a CO chondrite) is significantly too high based upon our measurements of strengths: this likely reflects that the tensile strength for Kainsaz was derived from a theoretical model [4]. The porosity of the other CO falls range between 9.2 % (Lancé, fell 1872) and 34.2 % (Ornans, fell 1868) [5] with a mean of 19.6 %, very close to that observed for Moss. The Moss bulk density is within the range for the other CO falls, between 2.81 g/cm^3 (Felix, fell 1900) and 3.42 g/cm^3 (Ornans) [5] and Moss grain density is very close to the range of the other CO falls, from 3.50 g/cm^3 (Kainsaz, fell 1937) and 3.70 g/cm^3 (Warrenton, fell 1877) [5]. Moss`s bulk density excludes this CO lithology from composing asteroid Bennu since, as a macroporosity maximum limit (due to packing considerations) of ~50 % implies the lowest possible rubble-pile-asteroid density of ~ 1.46 g/cm^3 which is significantly higher than the Bennu density obtained by the OSIRIS-REx mission of 1.19 g/cm^3 ± 0.013 g/cm^3[1].

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