Joint glossary for planetary scientists and architects: interdisciplinary attempt under ArchiSpace project

Kereszturi A.[1], Ori G.G.[2,3], Allemand P.[4], Bacaoui A.[5], Bier H.[6], Ribeiro T.[7], Correira M.[7], Mancini F.[3]

[1]Konkoly Astronomical Institute, CSFK, HUN-REN, Hungary; [2]International Research School on Planetary Sciences SRL, 65128, Pescara, Italy; [3]Universita Degli Studi Gabriele D'annunzio Di Chieti-Pescara, 66013, Chiéti, Italy; [4]Universite Lyon 1 Claude Bernard, 69622, Lyon, France; [5]Université Cadi Ayyad, Marrakech, Morocco; [6]Technische Universiteit Delft, Architecture Department, 2628 CN, The Netherlands; [7] Department of Architecture & Multimedia Gallaecia, CIAUD-UPT, Portucalense University, Porto, 4200-072, Portugal Email: kereszturi.akos@csfk.org

INTRODUCTION & AIM

In Situ Resource Utilization (ISRU 1,2) activities including local material based building works are planned for the missions targeting the Moon and Mars in the next decades, as well as rare elements and water extraction from asteroids (3). Although preparation for such missions are going on, interaction and collaborative work between architects, engineers, Earth and planetary scientists (four main mains domains considered in this work hereafter) have not been well formulated yet. To support such synergic activities, under the EU funded ArchiSpace project (101183089) a joint glossary is being developed to see how researchers from these different domains consider the same basic terms

METHOD

Using literature survey a first list as a glossary is presented, containing both architecture, engineering, Earth and planetary science topics. Using the knowledge of the community and the general view, several important comparative aspects have been considered. The terms used in this glossary are accompanied with related aspects of classical architecture and engineering domains, as well as their corresponding information from Earth and planetary science

RESULTS

Differences between the three planetary bodies are reflected in specific relevant aspects for architecture and Earth plus planetary sciences, summarized in Table 1. Some of the general findings of the comparison:

- Lower gravity allows the usage of less amount or weaker construction materials, what could be handled by engineering calculations.
- Rarity and lack of atmosphere rises specific questions, usually not handled by regular building protocols and requires specific technology
- Usage of local materials has wide background and experience on the Earth in native building methods.
- Some challenges are new for architectures including radiation, vacuum, micrometeorite impacts with poorly explored consequences.
- Some challenges are new for planetary scientists including design aspects, effect on human moods and behaviour, also to be explored.

CONCLUSION

There are specific meanings for almost all considered terms at different domains with focusing on their specific characteristics. Corresponding links are present between the versions how different domains consider a given key term (like soil, cementation, compaction). The specific terms related knowledge between different domains could be interconnected, however the information transfer between them is not straightforward and requires further improvement. Such transfer on key terms can be supported by numerical values (density, adhesion, composition, grain size), which should be tested by case studies for Moon and Mars surface habitat planning. The glossary will be presented at the meeting and the ongoing work welcomes contributors from various but mainly the architecture and engineering related topics.

REFERENCES

References:
1. Jared et al. 2026. Planetary and Space Science 270, id.106229
2. Gross et al. 2024. Acta Astronautica 223, 15-24
3. Trigo-Rodríguez et al. MNRAS 545(1), staf1902
4. Cooke R. (1993) Desert Geomorphology, Publ. by UCL Press
5. Atwood-Stone C. and McEwen A.S. 2013. 44th LPSC, #1727.

Table 1. Summary of planetary relevant aspects of analogue sites for building habitats on Moon and Mars.

	Definition, general aspects	Architectural aspects	Earth science	Planetary science
Soil	Weathered top part of modified bedrock by external physical and chemical effects	mechanical and chemical properties important for habitat localization and building	Separation of biological effects should help	Characteristics of Martian and Lunar regolith, separation of different units
Bad-lands	landscape produced by incision and erosion of weakly cohesive rocks (deep gullies, steep ridges, mesas and buttes), no vegetation	estimation of bedrock stability and erodibility, consideration of basement rock to place the habitat	Well testable at desert terrain, measurable field data available	Mars: wide occurrence of badlands, their characteristics (current estimation: mainly tuffs). Not relevant for the Moon
Hard-pan	cemented part of unconsolidated sediments, often in shallow depth by precipitation from groundwater	effecting both raw material exploitation and basement stability of buildings	in deserts, depending on location and composition, points to formation	Mars: cement of duricrust; Moon: agglutinates, impact driven melt sheets and -ponds
Pave-ment	(1) bare rock surface, (2) material spread on the subgrade to distribute load and protect against erosion		Considered for loading and stability aspects, supported by laboratory based compression measurements	Moon and Mars: bedrock outcrops, fragmented boulder fields, weathering / ground water cemented layers
Duri-crust	Hardened surface horizons by precipitation (ferricrete by iron oxide, calcrete' by calcium carbonate and 'silcrete' by silica)	evaluation of stronger local material for potential usage, artificial duricrust formation might provide useful perspective	Different forms, including desert pavement with grain cementation, chemical changes and deposited dust	Mars: exists at many location mainly by sulfate cemented grains, but humidity could also contribute. Moon: agglutinates might produce resemble feature.
Stone-pavement	flat desert area with rounded pebbles or gravel cover often as lag deposit	usage and estimation for basement stability considerations	characteristics and occurrence at analogue sites on the Earth	characteristics and occurrence at analogue sites on Moon (if relevant) and Mars
Soil stabilization	improving the properties of soil in workability, placeability, compatibility and strength	cost / benefit comparison of cementation or compaction driven hardening	regolith stabilization at soil poor terrains using purely local resources	evaluation of specific local regolith characteristics for hardening and solidification on the Moon and Mars
grain cement	Adhesion between grains, influence the processing mode and usage of the regolith	evaluation of grain adhesion, specific melting/solidification characteristics	Laboratory based grain size, shape, mineralogy surface roughness, data	Regolith properties, data from landers and orbiters
Cohesion	attraction between particles, producing strength, influenced by pore-water suction	useful for numerical calculation, might be decreased by drying	usually carbonate cement, but H_2O occurrence also influences	evaluating influencing factors like grain size shape and occurrence / role of cement. Mars: sulphates, H_2O; Moon: agglutinates
Cementation	clastic sediments lithified by precipitation of mineral cement, forming integral part of the rock.	estimation of stability, erodibility, and difficulty of drilling and excavation	mechanical properties are testable at Earth based locations	Moon: agglutinate and melt pond formation. Mars: sulphate + iron-oxide based cementation, duricrust, subsurface ice as cement
Compaction	physical processes produce dense coherent rock from loose sediment produced by expelling air by the dynamic loading (e.g. by rolling or vibration).	influences the processing of raw materials, subsequent reorganization of grains, as well as compacting below basement of the habitat.	Strongly target material dependent, both on grain size distribution and grain shapes plus their surface roughness	should be estimated from landing pad penetration and wheel tracks, completed with laboratory tests of regolith simulants
Case hardening	induration of the surface of porous rocks by infilling of pores by mineral cements from evaporating moisture or groundwater	influences mechanical stability, thermal insulation, and erodibility of external surfaces	could be evaluated its specifics of raw materials at desert terrains and dryness there	Mars: variable cementing agents, for old Noach. sediments phyllosilicates and carbonates, Hesp. sulphates, Amaz. current: hydroxides, various salts
Burial diagenesis	physical, chemical and biological processes of sediment during burial by metamorphism or structural changes by mineral and mechanical modifications	considered as properties of raw materials, and as habitat installation, might produce diagenesis related effects	estimated using local lithological and climatic conditions	Moon: mainly by large impact ejected material (by >100 km category craters). Mars: low pressure conditions (no plate tectonism, only by ice or sediment burial driven up to few km thickness under educed gravity)
Sintering	bonding of powdered materials by chemical reactions	evaluation of sintering, relation to mechanical and thermal properties	classical methodologies used in building from local raw materials	tests have been realized by various reglith simulant materials
Induration	hardening of sediments into rock by pressure, heat or cementation	may be relevant for building purposes	by compaction and cement formation, pore water also supports	Mars: cement of duricrust; Moon: agglutinate formation, impact driven melt sheets and -ponds
Compr. index	reduction in void ratio by the increase in effective stress	useful to estimate the behaviour of processed material	grain size, composition and structure dependent	poorly evaluated for Moon and Mars, azalogue material should be tested in laboratories
Angle of repose	Max. angle at which unconsolidated material stands, influenced by particle size and angularity, degree of interlocking between particles, and pore-water pressure. For coarse grains: 32–36°	should be evaluated during planning of various construction operations	Evaluation of grain size and shape aspects, typical desert sand dunes ranges between 30° and 35° (4)	Moon: regolith maturity and agglutinate content dependent, bur usually no above about 30 degrees. Mars: 30°-35° (5)
Elasti-city	Deformation from strain with possible subsequent complete recovery (stiffness).	should be considered during planning and statistical calculations	testable at analogue terrains to understand planetary desers	should be evaluated as habitat building and local traversing could modify local regolith masses
Erodibility	resistance of to the entrainment and transport by erosion, controlled by mechanical and chemical properties	influences the surroundings of habitats and various activities	case studies and examples of which terrains and how became erodible, how influencing local activity	specific aspects could have long term effects on human interaction, Mars: traversing and habitat weight could influence and increase erosion
Gap grading	particle-size distribution with one particular size is absent	could influence the construction operations and stability of buildings	measurable, might be influenced by wind driven grain separation	Moon: regolith maturity related, influenced by agglutinates also; Mars: mainly wind driven effects influence
Porosity	pore voids within a rock, may be occupied by fluid of gas, measured as the ratio of volume of voids in a soil to its total volume.	could be modified by the building methodology, since increased porosity increases heat insulation capacity	characteristic values are present for different lithologies	Moon: decreases from >50% to <10% in 1-3 m. Mars: probably lower values than on the Moon. Decreasing porosity increases radiation shielding of habitats
Wind pressure	by atmospheric wind according to speed and air density, influenced by habitat shape, produces uplift or shear, critical in structural engineering and for integrity	shape of building is informed by structural requirements against wind pressure	Meteorological data from Earth, weak pressure and strong wind sped related changes and range of values	Measured wind speeds on Mars, daily and seasonal changes, annual pressure cycle. Not relevant for the Moon
Precpi-tation	Liquid / solid volatile falling- con-densation. Influences external surfaces, provides protection	chemical and physical corrosion processes that affect the building	Precipitation, snow ice characteristics, seasonal cycles, freezing periods	Mars: spatial and temporal occurrence of snow and ice, contribute in corrosion, might substantially cool external surfaces
Temperature	Influences the material stability and used process / effort of building; while also influences the indoor habitability	relevant for indoor comfort and energy management	Usually close to human needs, ice as building material used rarely, only at polar terrains	Extreme external values might be present, but occasionally with poor heat transfer cooling might be also needed
Sunlight	Influences energy production but also indoor temperatures, while has effect on human moods	relevant for energy generation and comfort/ psychological wellbeing	Used for solar panel installation, regular windows need not withstand high atm. pressure difference	highly dependent on location, strong seasonal aspect exists on the Moon (14 days sunlight, 14 days darkness;
Earth-view	Variable, location and window attitude dependent, influences human moods	relevant for psychological wellbeing, as well as internal design	usually planned to provide "nice" view for humans, however might cost extra effort to provide	Oin hte Moon the sky is always dark (no whitish-bluish), on Mars daytime reddish-whitish, while in dust storms darker brownish
Meteorites	Microscopic impact is present on the Moon, making producing microscale melting and vaporization	may affect structural integrity and micro-scale structure of external surfaces	does not exist on the Earth and on Mars	Mitigation requires cm thick external expendable surface on the Moon, which degradation does not cause problem in decades
Atm. pressure	External atmospheric pressure from the surrounding gas (excluding wind pressure)	difference between out- and indoor pressure may affect structural integrity	Not relevant on the Earth	High on Mars and even higher (1 atm. versus vacuum) for the Moon, heavily influences mechanical stability
Water	Used for various chemical reactions during the processing of building materials	required for construction and operation of habitat	Often abundant but could be moderately easily transported to building locations	Few on the Moon (with possible limited amount at some polar locations), available during wintertime at high latitude on Mars
Regolith	used as building material, its component, and influences the stability of the basement for buildings	required for construction of habitat	widely used in native building methods, but usually not proper basement material four habitats	Covers most of the Lunar and Martian surface, expected vertical differences on the Moon from ejecta stratigraphy, on Mars influenced manly by weathering

This work was supported by the EU funded ArchiSpace (101183089) project.