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CONSTRUCTION MATERIALS AND TECHNIQUES IN PERSIAN ARCHITECTURE
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# CONSTRUCTION MATERIALS AND TECHNIQUES IN PERSIAN ARCHITECTURE

**CONSTRUCTION MATERIALS** AND **TECHNIQUES** in Persian architecture.

Materials

*Mud.* The most frequent building material in Iranian cultural areas has always been mud, which is available everywhere. When wet, it can simply be plastered on walls without shaping. Alternatively, it can be tempered and formed into large blocks with more or less rectangular sides; the most common dimensions of such blocks, even today, are about 80 x 80 x 60 cm. Mud can also be manufactured into bricks and either dried (*ḵešt*) in the sun or baked (*ājor*). Sun-dried mud bricks were generally larger in antiquity and the early Middle Ages than they are today. For example, those used in Urartian (7th and 8th centuries b.c.e.) fortress walls measured about 50 x 50 x 12 cm (Kleiss, 1977), whereas modern mud bricks are approximately 22 x 22 x 5-6 cm. Plano-convex bricks, which are shaped like cushions or bread loaves, with one flat and one convex face, first appeared in Persia in the 8th-7th millennia b.c.e. in the walls of the Neolithic settlement at Tepe Ganj Dareh (Ganj Darrah Tappa) in Kurdistan (Smith), where they were set in mud mortar. Sun-dried mud bricks, usually quadratic in form, predominated until the end of the Achaemenid period. In the 2nd millennium b.c.e. painted and glazed bricks

were also used in Elam. Under the Parthians (3rd century b.c.e.-3rd century c.e.) and especially the Sasanians (3rd-7th centuries c.e.) large baked bricks set in mortar became more and more common in Persia. In about the 10th century molded, cut, and relief-carved bricks, often painted or glazed as well, became a significant feature of Persian architectural decoration.

*Rubble.* In prehistoric and early historic times rubble, naturally fragmented or deliberately chipped rock of no specific shape, was the most frequent building material after mud; it was used primarily in foundation walls, on top of which the main walls were constructed of mud (packed [*čīna*], chunks, or bricks). The rubble walls consisted mainly of flat pieces of stone, which were carefully laid with loose pebbles filling the interstices; the whole was cemented with mud mortar. In historical times lime mortar has also been used.

*Cut stone.* Cut-stone architecture appeared in Persia in the Urartian period, around the beginning of the 1st millennium b.c.e. Sometimes mighty stone boulders weighing several tons were broken up into smaller pieces and used in construction. For example, in the terrace at Persepolis such man-made boulders were laid in courses with small, crudely hewn stones filling the gaps. Whether or not these wall surfaces, which were frequently marred by convex humps and roughhewn edges or with protective rims projecting along the edges, were meant to be evened and smoothed often cannot be determined. Stone architectural members—like column bases, shafts, and capitals; door sills, frames, and jambs; wall niches; cornices; crenellations; and other special forms—were crudely worked with iron tools as early as the Achaemenid period, probably under the technical influence of Greek stonemasons.

*Wood.* Another building material was wood, from both coniferous and deciduous trees, especially poplar; it is still important today for supports and roof construction in the traditional rural architecture of Persia. Roofs and ceilings are constructed of logs, across which smaller wooden boards are laid and on top of them reed mats or thatch; the whole is then covered with mud, which has first been levigated and tempered with straw, for “insulation.” Along the Caspian Sea coast wooden architecture predominates, particularly post-and-lintel houses with thatched roofs. In the Sasanian period wood also played a role in construction of bridges; it must be assumed that the large number of bridges known from this period consisted of horizontal wooden structures resting on top of stone piers. On the other hand, in the Islamic period bridges were built primarily of stone or brick and vaulted; wood played only a subordinate role in such constructions, being used for scaffolding,

building forms, pulley weights, temporary supports, and often for reinforcement in the vaulting.

*Gravel and paving.* In ancient, medieval, and modern times road embankments have been constructed of gravel, either coarse or fine, and paved with relatively unworked stone blocks. In Islamic cities brick was sometimes used to pave major streets (Kiani, pp. 230ff.).

Techniques

*Preparing the site.* Already in ancient Persia, as in Hittite Anatolia in the 2nd millennium b.c.e., the technique of making use of the rock surface of a site as foundations for walls was known. In the 8th and 7th centuries b.c.e. the Urartians developed this technique to the highest level of perfection (Kleiss, 1976, pp. 28 ff.). Flat terraces of different sizes and elevations were carved out of the uneven rock surface following the specific conformation of the site, thus preparing a series of level platforms of the required dimensions, on each of which walls could be erected. Those parts of the rock on which there was to be no construction were generally left unworked. The Achaemenids also made extensive use of this technique at Persepolis and other sites. They had probably learned it from the Armenians, who had received it as part of their cultural heritage from the Urartians. Whereas in Urartu, however, rubble or ashlar walls rested on terraces hacked out of living rock or on leveled rock surfaces, in the Achaemenid period such rock-cut terraces served as foundations for walls of mud brick (Kleiss, 1971).

In preparing the site, for example, that of an Urartian temple, recesses for plaques containing foundation inscriptions were frequently cut into the rock at the points where the corners of the walls were to rest (Kleiss, 1963-64). Drainage channels were also hollowed out of the rock surface at several points before the walls were constructed; after the walls were built their function was to drain off groundwater that collected inside the walls and thus to keep them dry (Kleiss, 1976, pp. 28-29). In the Urartian and the ensuing Median periods staircase passages were also cut through the living rock, in order to ensure the provision of water during a siege; whenever possible natural crevices in the stone platforms were exploited for this purpose. Normally such a staircase led from within a fortress to an underground well or spring (Kleiss, 1979, p. 154). All these early features were achieved by carving out the living rock with picks.

When the surface of the site was somewhat concave, rubble foundations, mostly for mud-brick walls, were generally preferred. Larger pieces of broken stone were carefully laid in courses with smaller stones filling the interstices; toward the top pebbles of diminishing size were used, in order to produce a level surface. In antiquity mud mortar was used, in the Middle Ages lime mortar. Over the top of the foundation there was a layer of white lime 1-2 cm thick, on which the lowest course of the mud-brick wall rested. This layer of lime was obviously intended as a damp course, to prevent ground moisture from rising through the unmortared dry wall of the foundation into the mud-brick walls and causing them to collapse. In Urartian architecture rubble foundations were constructed as stepped terraces, in order to save stone; the dimensions of the topmost surface were determined by the width of the mud-brick wall to be erected on it (Kleiss, 1977, pp. 35-36).

*Walls.* The upper walls were normally coated with plaster. In ancient times mud-brick walls were usually plastered with mud tempered with chaff. Lime plaster, known from as early as the Neolithic, became common in the Urartian and Achaemenid periods. Evenly spaced projections from the walls served the primarily aesthetic purpose of articulating the facade, but in rare instances they also served to buttress the construction or even as part of the fortifications.

*Vaults.* Vaulting became common in Persia in the 2nd millennium b.c.e.; in fact genuine vaults of baked brick with gypsum mortar had already been introduced, for example, at the Elamite site of Haft Tepe (Negahban). Semicircular vault forms are depicted in Urartian architectural representations, and they are also known from bridge constructions of the Sasanian period, for example, the so-called “bridge of Valerian” at Šūštar, which is considered to have been built by Roman engineers after 260 c.e. Parabolic vault forms began to appear in Sasanian architecture. From early in the Islamic period the pointed arch was also in use in stone and mud-brick construction, as well as in buildings of baked brick. The original tall, pointed profile of this type of arch became progressively wider and shallower until the 17-18th centuries, especially in bridge construction. In the 19th century the European round arch gained increasing influence; by the end of the century it had, however, given way to the basket-shaped arch with its much wider span, again especially in bridge construction. A particular feature of Islamic architecture from the 11th century was *moqarnas* (oversailing courses of small niche sections) vaulting, which became increasingly common with the passage

of time. Such vaults could be constructed of stone or bricks but were more often simply decorative shells carved from gypsum or limestone mortar (Harb). They were particularly popular as interior architectural decoration but also sometimes appeared on building exteriors, especially facades.

*Quarrying.* Whenever possible quarrying was carried out where stratified stone was bedded horizontally and would fracture in sheets. Blocks could then be cut from the sheets with chisels or crowbars at no great expense, rendering deep shafts and the use of wedges unnecessary (Kleiss, 1981, pp. 197-98). In Achaemenid quarries wedge-shaped holes averaging about 20 cm long, 8 cm wide, and 8-10 cm deep can be observed at wide intervals. In the quarry south of the terrace at Persepolis rough passages or channels had been cut around the blocks; wooden wedges had then been driven into the rock at the back, in order to split off the stone blocks in parallel layers. A road paved with stone chips linked the quarry face to the workings along the upper facade and an adjacent terrace (Kleiss, 1975, pp. 81 ff.). In the Sasanian period, too, straight channels 30-50 cm deep were cut into the rock and wedge-shaped holes closely spaced along them. This technique was lost until recent times and was only reintroduced in connection with modern construction methods.

*Clamps.* From the Achaemenid period onward metal clamps, mostly of iron, were used in ashlar construction. Some were simple bands, but clamps in the form of swallowtails were more frequent (Schmidt, I, pp. 61-63; Kleiss and Calmeyer). In the Sasanian period band-shaped iron clamps were used most often, for example, on the facing walls of bridge piers. The clamps were cast in lead molds.

*Earthen dams.* One specifically Persian feature is found in bridge building: earthen dams with paved surfaces. Although they have also occasionally occurred in other cultures, they are particularly frequent in Persia. These dams were as a rule intended to provide protection from the periodic extreme variations in water levels in the streams, which might undermine bridge piers. They were also useful in diverting streams into subsidiary canals for irrigation purposes.

*Mortaring.* Either lime or gypsum mortar was used, depending on the required degree of durability and the necessity for special protection, as in bridge piers or canal walls, which were subject to the continuous action of water. Important differences can be observed in the consistency of the mortar used in the piers and in the vaulted portions of the bridge. In order to articulate the

otherwise monotonous wall surface, in early Islamic architecture mortar-filled vertical joints were made thicker than the horizontal joints and decorated with stamped or incised designs.

*Stonemasons' marks.* Stonemasons' marks are known in Persian architecture from the Achaemenid period, owing to Greek influence (Stronach, pp. 21-22); before that time they were not known in Persia. They were used in work on large buildings, in order to document the performance of the individual stonemasons and to serve as an aid in reckoning payment. A few basic forms, like the circle, the cross, the triangle, the rectangle, and the open rectangle, recurred in all periods, from the time of the Achaemenids until the reign of the Qajar dynasty (1193-1341/1779-1924); it is therefore clear that the equal-armed cross had nothing to do with identifying Christian workmen. In comparing the repertoire of stonemasons' marks at different Achaemenid building sites, there are no immediately apparent differences that can be taken as evidence for identifying different workshops or different historical periods (Kleiss, 1980). The same is true of stonemasons' marks in Sasanian and early Islamic architecture, as well as in the buildings of the period from the Safavids through the Qajars.

*Achieving color effects.* In Achaemenid architecture color effects were achieved mainly through the use of stones of different hues, for example, in column bases. This technique was already known in the Urartian period and was passed on to the Armenians, who have continued to make use of it until modern times; it was probably through them that it came to be adopted for medieval Saljuq architecture. Traces of color remaining on some Achaemenid architectural elements suggest that certain parts of buildings were at least partially painted. Red marks were also used as an aid in joining together different building elements in the Achaemenid palaces at Pasargadae and as guidelines for squaring and smoothing the building blocks.

*Tools.* The oldest stone-working tool so far known from Persia is an iron chisel found in the Urartian fortress at Besṭām, dating from the 7th century b.c.e. It was built into the upper leveling courses of the stone foundations of the wall and surrounded on all sides by mud; it is thus to be associated with the original dedication of the building. It is 19.8 cm long and 5.7 cm wide and would have lent itself to the cutting away of the stepped terraces of the rocky subfoundation, as well as to secondary working of building stone. It has a chisel-shaped point (Kleiss, 1979a, I, pp. 84-85). Under Darius I a toothed chisel was employed only occasionally, but it did not come into general use until

somewhat later, when it was introduced by Greek stonemasons (Nylander, pp. 53-56; Stronach, pp. 99-100). In stone architecture flat chisels were used to cut deep, narrow channels around projecting blocks; traces of this work are still clearly visible. They were also used in the subsequent crude shaping of the blocks. The final smoothing of the stone surface must have been accomplished by means of abrasion with harder stones in conjunction with water and fine sand.

*Transport.* The question of how doorjambs, column shafts, and capitals were transported from the Achaemenid period onward can be answered only by assuming that level tracks were prepared. The partly worked stone blocks, like those in the terrace at Persepolis, were brought on wheels drawn by work animals over inclined tracks leading to the construction area.

*Laying out the plan.* Measuring apparatus must also have been used in laying out building sites, but no ancient examples of such apparatus are known. The precise planning and execution of buildings, already apparent in the Urartian period but even more highly developed under the Achaemenids, would nevertheless have necessitated such instruments. A proposed building, whether a single structure or a larger complex, like the Urartian fortress at Besṭām and the structures at Pasargadae and Persepolis, was marked out precisely on the site, as can be recognized from the rock cutting at Besṭām and in the Kūh-e Raḥmat at Persepolis. Only those parts of the rock on which a specific part of the building, for example, a buttress, a support, or a jog in the course of the wall was planned, were cut away; it was done so precisely that, even where the walls have completely disappeared, the outline of the plan can be clearly gauged by the limits of the rock cutting.

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