Ball Clay Production in Iran

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Abstract
Ball clay has been defined technically as a fine-grained sedimentary plastic clay in which the clay mineral kaolinite predominates. In Iran, the main ball clay deposits of economic significance occur in Tabas area which is located at northeast of Yazd province in center of the country. According to geological setting of the deposits, it seems that the ball clays have been formed in the swamp-like lakes under sub-tropical conditions and are of Lower Jurassic in age. From the viewpoint of mineralogy, the clays are composed predominantly of kaolinite, illite, and fine quartz, with a minor amount of mixed-layer clay minerals and carbonaceous material. The Tabas mines show several distinct seams of ball clay with different chemical, mineralogical and ceramic properties, which are mined selectively for different end-uses.

Introduction
Ball clay can be defined as a kaolinitic sedimentary clay deposited under freshwater or brackish conditions. The kaolinite in ball clay is generally finer grained than in china clay, having a particle size that ranges ۵۰–۹۰٪ <۲ μm, and it is often ß-axis disordered.
Ball clays are composed predominantly of kaolinite, illitic mica or sericite, and fine quartz, with a minor amount of mixed layer mineral, smectite and carbonaceous material. The most commonly occurring contaminants (with respect to a clay's suitability for fine ceramic applications) are pyrite, siderite, anatase, gypsum and dolomite.
Ball clay is an important component in most ceramic bodies, where it is used to provide strength and plasticity to the unfired piece. Some of the Iranian ball clays, especially Tabas ball clays, are renowned for their low iron content, and many have favorable fluid properties for ceramic applications. The higher-quality ball clays have a light-cream to white fired color.
The term "ball clay" is derived from the original method of working the deposits in southwest England. Specialized hand tools known as "thirting spades," "tubils" and "poges" were used to cut ۲۳-in. (۹-cm) cubes of clay from a quarry bench. Through handling and transportation, the cubes gradually lost their corners and became rounded "balls" by the time they reached the potter. In early times, the clay was actually sold by the ball. During the ۱۷th and ۱۸th centuries, the demand for tobacco pipes provided the first impetus for ball clay mining; this resulted in the alternative term "pipe clay." "Plastic clay" is another name that is commonly used for ball clay.

Location of Ball Clay Deposits

In the Iran, ball clay deposits of economic significance occur mainly in two areas, which are located in the central part of the country. One of them is the Abadeh fire clay mine, which is located in ۱۸۰ Km distance from Esfahan in Abadeh direction. The mine, which is operated by Baztab Mehr Abadeh Company, with a reserve more than ۲۰ million tons can produce varieties of ball clay in titled of Abadeh Fire Clays. Another one is Tabas ball clay mines, which are located in North East of Yazd province. The Suravajin Aghigh Mining & Industrial Company (SAMICO) is the major producer of this area and has operations in largest mines. This article focuses on the SAMICO operations in the Tabas area.

Geology of Tabas Ball Clay Deposits

The commercial ball clay deposits are confined to Robat-e-Khan Jurassic basin that is situated at the west of Tabas in central Iran geostructural zone. From the view point of stratigraphy, these Ball Clay deposits seams to be part of the continental sediments (as known Ab-e-Haji Formation) which are of the lower Jurassic age and were formed in the lagoon basins under the tropical conditions. The climate in the upper Triassic-lower Jurassic period was sub-tropical and the very warm and wet conditions resulted in a deep weathering of the ancient granite uplands. The feldspar minerals within the granite were changed to a moderately ordered kaolinite. Further movement and erosion along the local fault system resulted in a large valley. Sediments derived from the erosion of the thick weathering were channeled into this valley by rivers. The coarser sands and gravels formed alluvial sheets or fans on the valley floor and the clay, silt and vegetation debris accumulated in the swamp-like lakes. The tectonic basin was area of crustal weakness which enabled the slow accumulation of ball clays, unconsolidated sands and lignites. Subsidence of the valley floor in the basin area was probably linked to periods of earthquake activity and movement on the fault system.

About nine Ball Clay seam are recognized in the area. The physical, chemical, and mineralogical characteristics of the Ball Clay are seams to be very various. The ball clay mineralogy comprises varying proportions of disordered or ordered kaolinite, illite and quartz with a minor amount of mixed - layer clay minerals and organic materials.

Production Method

Because of the dip of ball clay seams, that is range from ۱۰° to ۸۰°, and the existence of a very hard and thick overburden (mainly quartzitic sandstone); the mining methods, which are used in the mines for the Tabas deposits, are both open-pit and underground.

SAMICO uses a selective mining method in the Tabas area. Every seam is extracted, transported, and stored separately so that blending can be

effectively conducted to produce a wide range of tailored products for the consumer. An excavator working on the full dip of the sequence is used to extract each ball clay seam as per the face survey. The excavator operator can actually feel a change in the resistance of the clay to the machine bucket and extract the different ball clays separately. Small, articulated dump trucks (capacity ١٠-١٢ tons) are used to carry the ball clay from the face to the bulk storage.

Some of the bulk clay selections are sold individually, but it is mainly necessary to blend various ball clays to achieve the optimum characteristics for a given application. Component clays are loaded from the bulk storage sheds into trucks (following a specific product recipe) using loading shovels with weighing mechanisms. These then tip the blend into a crusher. This process homogenizes the blend and decreases the lumps down to ٥ cm nominal size.

The characteristics of main ball clay products of SAMICO from Tabas area are illustrated in following tables.

RB Group:

Chemical Compounds	A-RB-١٠	A-RB-٢٠	A-RB-٣٠	A-RB-٥٠
SiO_2	٤٩,٥	٦٠,٠٠	٣٨,٠٠	٧٥,٢
Al_2O_3	> ٢٨	٢٢,٠٠	٢٦,٠٠	١٥,٨
Fe_2O_3	< ١,٥	<٢	١,٠٠	٠,٨١
TiO_2	< ١,٥	١,٥ - ٢	١,٠٠	١,٠٨
CaO	< ٠,٥	< ٠,٥	٠,٥٠	-------
Na_2O	< ٠,٥	< ٠,٥	٠,٥٠	-------
K_2O	< ١,٥	< ٢	٢,٠٠	-------
SO_3	< ٠,٨٥	< ١,٥	< ١	٠,٣٣
L.O.I	< ١٧	١٠	< ٣٠	٤,٥٠
P.C.E	٢٩	-------	-------	-------
Mineralogical Composition	Quartz, Kaolinite Illite (min) Organic material (min)	Quartz, Kaolinite Illite (min) Organic material (min)	Kaolinite Quartz Organic Material Illite(min)	Quartz Kaolinite Illite
Recommended Application	Refractory Binder Tile Industrial Ceramic	Refractory Binder Tile, Sanitary ware Industrial Ceramic	Construction Ceramic Refractories	

RK Group:

Chemical Compounds	A-RK-١٠	A-RK-٢٠	A-RK-٤٠	A-RK-٥٠
SiO_2	٦٢,٥٠	٦٨,٥٠	<٦٤	٦٦,٠٤
Al_2O_3	٢٢ - ٢٤	١٦,٠٠	١٨,٢٠	١٩ - ٢٠
Fe_2O_3	< ١,٦	< ١,٨	٠,٧٠	٠,٦٤
TiO_2	< ١,٥	<١,٥٠	-------	١,٥
CaO	٠,٥٠	٠,٥٠	-------	٠,١٤
MgO	-------	-------	-------	٠,١٠
Na_2O	٠,٥٠	٠,٤٥	١,١٠	٠,٦٥
K_2O	٢,٣٠	٢,٥٠	٣,١٤	٢,٤٨
SO_3	< ١,٤٥	١,٥٠	<٢	٠,٦٤
L.O.I	٧,٥٠	٦,٥ - ٧	٩,٠٠	٥ - ٦
Mineralogical Composition	**Quartz Kaolinite Illite**	**Quartz Kaolinite Illite**	**Quartz Kaolinite Illite**	**Quartz Kaolinite Pyrophilite Illite**
Recommended Application	**Sanitary ware Floor Tile Porcelain tile Ceramic**	**Tile, Ceramic General Purpose**	**Tile, Ceramic General Purpose**	**Ceramic Porcelain tile Ceramic**

Quality Control

Quality control is an important aspect of SAMICO in the production of consistent quality ball clay. Each of the production face in various quarries have been surveyed, in which trenches and channel samples of each ball clay seam are taken before the material is dug. These samples then are analyzed by the quarry's laboratory, and a clay selection is assigned. This data is given to the excavator driver, who is charged with extracting the material as per the face survey.

The various ball clay selections are characterized by their chemical analysis, fired color (at ١٢٠٠°C), loss on ignition and dried strength. The fluid properties and rheological characteristics of the ball clays also are important for determining its suitability in sanitary ware applications.

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