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Use of Mica Mineral Powder in Bricks Industry to Improve the Performances

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In this work, the usability of mica mineral powder as an additive material in industrial brick were investigated. Mica mineral was acquired from an inactive mica mine which is located at the south of Shahrod, Semnan, Iran and industrial brick mortar was obtained from a brick company in Damghan. Mica mineral and brick mortar were prepared for various processes of industrial brick investigation. Mica mineral were powdered and this powder in different proportions was mixed with industrial brick mortar, starting amount of 0 wt % up to 15 wt % in 54-10 mm bar shape. Bars for testing of physico-mechanical properties of the samples having different mica mineral powder composition. These prepared bars were uniaxially pressed and sintered at the 1100 ºC during 1 h. It was found that the amount of mica mineral additive had positive effect on the physical, chemical and mechanical strength of the produced industrial brick. With increasing demands of the construction industry, bricks quality and cost become more important day by day in Iran. In addition, the usage of mica mineral powder for the production of industrial bricks has significant important role on reacting the local mica mine and local jobs for populace along with a great contributions to economy and ecology of the country. In this study, the efficiency of mica powder additives to produce better bricks was suggested.

Key Words: Fired bricks, Building material, Bricks, Mica mineral, Additive, Clay.

INTRODUCTION

Nowadays, human kind commensurate with their requirements use different materials and building is the early inseparable human needs, so building materials particularly brick, have their magnitudes. There are different kinds of bricks and bricks can be divided into various groups according to their main mineral composition and their usage, namely silica, alumina, mullite, manganesite, dolomite, lightweight, insulation fired bricks, *etc*[1].

Bricks become homogeneous, harder and stronger due to the ceramic bond from the fusion phase of the silica and alumina clay constituents[2]. Bricks properties are affected as a result of physical, chemical and mineralogical alterations[3]. Besides brick cracks, compressive strength and water absorption are two major physical properties of bricks that are potential predictors of their ability to sustain weathering effects reasonably well without cracking[4]. The main factors involved in manufacturing bricks are the type of raw materials used and the firing temperature, both of which affect the final product[5]. Additives are frequently used in brick production and the selection of additives depends on the characteristics required such as strength or became light weight. Thus additives to raw materials to improve the final behaviours are common. One way to increase the strength capacity of bricks is to generate stronger bond in the clay body components. In the specimens containing mica mineral powder, there is a much better bonding among the additives caused by propinquity with the clays. Insomuch, mica is very analogous in composition to the raw materials used actually and contain materials that can also be helpful in the fabrication of bricks and its chemical composition. We fixed the temperature here and centralized on additives. Moreover, inactive mica mine were in around the local industrial brick factories. Hence, in this work, mica mineral powder used as an additive for manufacture of building clay bricks to first, improve the quality of brick factories products and bricks quality gradation and second, active this mine again and succeed to make a several local jobs for populace. Different amounts of mica mineral powder (0, 5, 10 and 15 %, by weight) were added to bar specimens and fired at 1100 ºC. The basic physical and mechanical properties of bar specimens including compressive strength, water absorption and apparent density were examined and assessed.

The objective of this work is to study the possibility to incorporate mica powder with clay to produce better bricks and degrade their properties and also reopening the local mica mine again.

EXPERIMENTAL

The raw materials used are mica mineral powder and common bricks mortar. Industrial brick mortar for the experimental studies was supplied by a brick company in Damghan, Iran. It was ready to press brick mortar. Mica mineral powders obtained from an inactive mica mine in 80 km Shahrod the south, Semnan, Iran (35 43' 32"N and 55 19' 34"E) and were used as an additive in commercial brick mortar. Mica mineral were grinded under 40 μm before the characterization studies. The characterization of raw materials included chemical composition (X-ray fluorescence, Bruker axe-S4 Explorer), mineralogical composition (X-ray diffraction, Bruker-binary V3) and thermal behaviour (differential thermal analysis, DTA Netzsch STA 409 PC/PG; thermogravi-metric analysis, Netzsch STA 409 PC/PG) and dilatometry (TMA-50, Shimadzu). Mixture containing 0-5-10-15 wt % mica powder (powdered with Retsch RM 200 electrical mill) was homogenized for 5 h in a planetary ball mill and unaixally pressed into bars (54 mm diagonal × 10 mm height); under a load 3000 psi for a 20 min 8 wt % water was added to the dried brick mixture before dry pressing. Subsequently, the bar shaped samples were dried at 110 ºC for 1 h. After the samples became dried, the weight of the brick samples was measured to calculate the weight losses after sintering. Then sintered at 1100 ºC for 1 h in a furnace (Barnstead 30400) with 12 ºC/min heating rate average. The samples were left to cool inside the furnace in its natural cooling rate. Weight of the samples were measured again after sintering process. The mechanical strength (compressive and flexural strength; Load Cell Model: H3-C3-2ST-6B) of the sintered specimens (average of three bodies for each value) was measured. Water absorption and the apparent density values were calculated by using the Australia standard methods[6-10]. The crystalline phases of the raw materials and the sintered bars sample were identified by X-ray diffraction (Bruker-binary V3) and thermal behaviour (differential thermal analysis; Netzsch STA 409 PC/PG and thermogravimetric analysis; Netzsch STA 409 PC/PG).

The density value of the mica mineral powders was around 2.84 g/cm^3. The bulk density value of mica powder was 2.76 g/cm^3. XRD result of the mica sample is given in Fig. 1 and it was observed that the main crystalline phase in there were mica as main; solid solution between muscovite and biotite and quartz, calcite, apatite, *etc.* as secondary phases. XRF result of the mica sample analysis is given in Table-1. XRD analysis of the commercial brick mortar was showed that it was contains mainly SiO_2 and the other minor peaks showing the sample also contains, illite, montmorillonite and kaolinite, *etc.* (Table-1).

Especially in clay minerals that consist of sheet silicates and serpentine minerals, crystal axis lengths and angles between crystal axes are very close to each other. As a result of this, the peaks are equivalent and found at approximately same places. The shortage of these similarities leads a difficulty on distinguishing their peaks in the X-ray diffraction diagram. For this reason, minerals belong to sheet silicates can be determined better with differential thermal analysis. Occurrences of exothermic and endothermic peaks with the help of heating the sample from 0-1100 ºC make it easier to differentiate from each others. Particle size distributions and DTA-TG diagrams of brick mortar are given in Figs. 2 and 3, respectively.

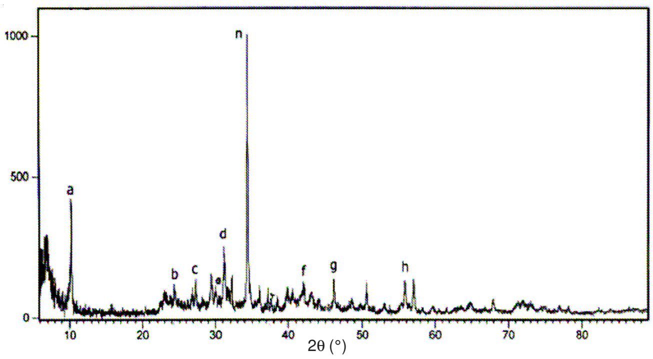

Fig. 1. XRD analysis of mica mineral (a-n-f-h) as biotite, (b) as muscovite, (c) as SiO_2, (g) as calcite, (d) as apatite

TABLE-1
MINERALS FOUND IN THE ANALYSIS OF BRICK MORTAR XRD

Mineral formula	PDF No.
Kaolinite [$Al_2Si_2O_5(OH)_4$]	29-1488
Montmorillonite [$Na_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2·4H_2O$]	29-1498
IIlite [$(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$]	26-911
Quartz Syn. (SiO_2)	46-1045
Calcite ($CaCo_3$)	47-1743
Muscovite 2M1 Syn. [$KAl_2Si_3AlO_{10}(OH)_2$]	07-0032
Dolomite [$CaMg(CO_3)_2$]	05-0622

Table-2 shows the chemical composition of the mica and industrial bricks mortar compounds (the plastic clay was prepared from tow samples; sandy sample and combinatory sample, with equal ratio) by XRF analysis.

TABLE-2
CHEMICAL COMPOSITION OF THE RAW MATERIALS WT %, DETERMINED BY XRF METHOD

Component (%)	Mica sample	Local common plastic clay	
		Sandy sample	Combinatory sample
SO_3	0.04	0.11	0.07
MgO	18.81	2.62	1.86
SrO	0.03	0.05	0.04
Cr_2O_3	0.06	–	–
MnO	0.07	–	–
Cl	0.08	–	–
Na_2O	0.78	0.78	0.71
TiO_2	0.93	0.63	0.60
CaO	2.02	13.43	13.85
K_2O	4.12	1.89	1.37
Fe_2O_3	10.25	4.15	3.55
Al_2O_3	17.49	9.91	8.02
SiO_2	37.74	50.81	54.93
L.O.I (1050, 1 h)	7.49	15.50	14.90

RESULTS AND DISCUSSION

Some of the physical and mechanical properties of the different mica percentage addition to bricks mortar like apparent density, water absorption are presented in Table-3.

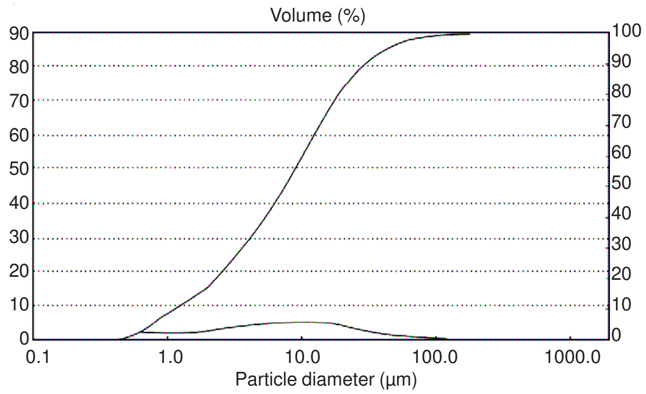

Fig. 2. Particle size distributions of brick mortar

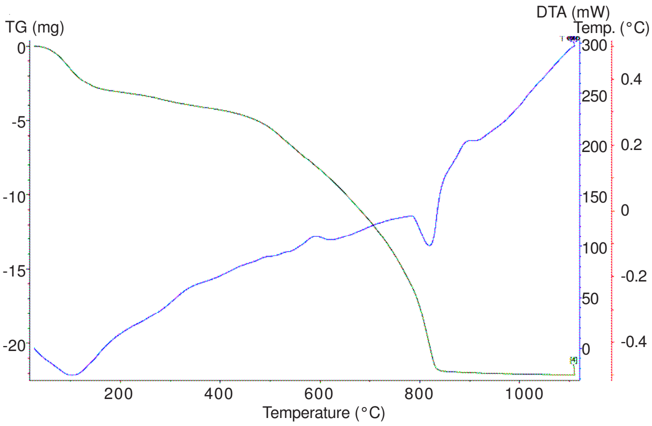

Fig. 3. DTA-TG diagrams of brick mortar

TABLE-3
EFFECT OF DIFFERENT MICA PERCENTAGE ADDITION ON THE PHYSICAL AND MECHANICAL PROPERTIES OF FIRED BRICKS

Properties	Proportion (wt %)			
	0	5	10	15
Apparent density average (g/cm^3)	3.71	3.58	3.34	3.16
Water absorption average (%)	17.57	17.94	18.81	19.42
Loss on ignition average (%)	17.30	17.65	16.41	15.88
Compressive strength average (kg/cm^2)	1310	2320	2357	2243
The samples length increased (bar diameter) (%)	5	5.5	5.9	6.2

It was observed that the increasing mica powder ratio in the mixture caused expanding of the samples. Normally clay mineral shrinks after sintering process. The mineral decomposed and result in shrinkage of the material, but mica powder mixtures exhibit an opposite behaviour especially when it contains a high proportion of mica powder. The main reason for the increase of the size is the occurrence of volatile and gases released.

This is a demanded property in brick manufacturing by increasing porosity, on the other hand decreases the weight of the material. Therefore, it could be used in the industrial brick mortar. At 1100 ºC, even 100 % brick mortar shows the growth in dimensions. The reason for growing of the sizes can be explained by the start of melting and the samples cannot maintain their shapes. 900 ºC is the ideal temperature for the shrinkage of samples.

The test results indicated that along with increasing the mica additive percentage to raw bricks mortar, apparent density decreased. The apparent density from 3.71 g/cm^3 for the control sample (0 % mica mineral powder percentage) slaked to 3.16 g/cm^3 for bricks with 15% mica powder additive. In other word, generally, the apparent density diminished almost linearly as 9.63 % and the bricks became more porous as increased the additive. However, the total density of fired bricks depends on several factors such as the specific gravity of raw materials, additives, methods of manufacturing and sintering temperature. The effect of mica additive on apparent density of bricks is plotted in Fig. 4.

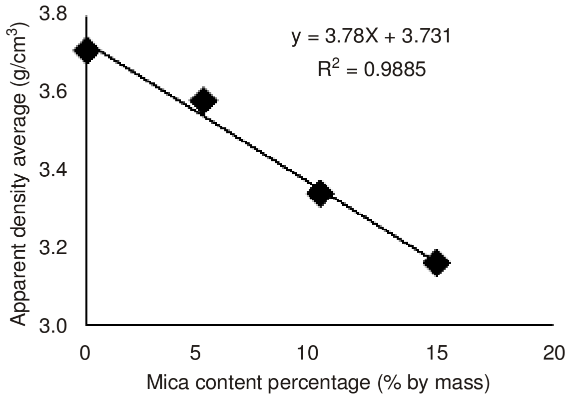

Fig. 4. Effect of mica content percentage on apparent density

Fig. 5 illustrates the water absorption diagram. Water absorption is one of the most important physical properties that shows the bricks quality and accordingly the quality of the bricks in water absorption was closely related to the porosity, sintering temperature, *etc*. Results represents that this parameter increased almost linearly with increasing in mica content percentage. It can be seen that the porosity values of mica powder mixed bricks increase with the increasing mica. The highest value of water absorption measured (19.41 %) occurred for 15 % mica contents and it was within the range of the Australian standard[6-10] (5-20 % water absorption is permitted). Water absorption capacity determines the ability and the potential performance of the bricks in buildings durability. High and low water absorption; both had bad affect on structure[11-15].

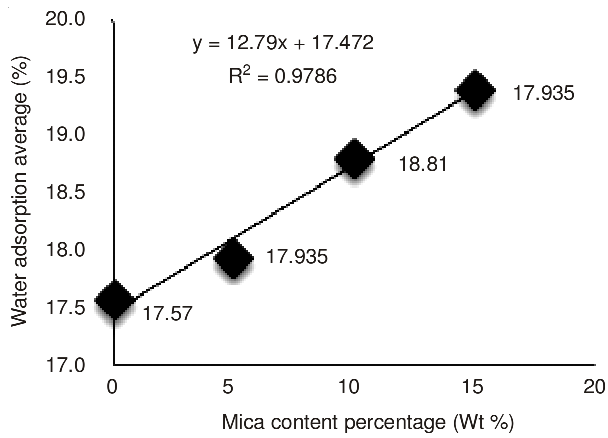

Fig. 5. Water absorption as a function of mica powder percentage contents

Another important mechanical property of bricks is strength and its resistances. The compressive strength is the most significant test that can be used to assure the engineering quality in the application of building materials. Generally the compressive strength of bricks tested was enhanced probably by chemical composition and chemical structure changes during annealing process but reduced along with the mica contents increasing. This slight reducing presumably caused by samples porosity increasing that agrees with the water absorption results. Fig. 6 shows the compressive strength test results of bricks with different rates of mica powders (0, 5, 10, 15 wt %). Generally, compressive strength is important for determining the load bearing capability of the bricks[11-15]. Fig. 6 showed that the mica powder percentage have significant influence on the compressive strength of the compositions. Porosity of the brick is increasing due to release of gases which results in adverse effects to compressive strength. The decreases in compressive strength in mica added bricks are expected results since the addition of mica powders in industrial brick mortar reduced the densities and increased the porosities. In bricks, strength values usually decrease with increasing porosities. However, this case may help strong isolation in building materials.

Fig. 7 shows the X-ray diffraction patterns of the fired bricks with different mica addition. It can be noted that all four patterns are almost resemble each other and constituted by quartz, Na, Ca and K feldspar series like anortite-labradorite-albite-orthoclase, gehlenite, pyroxene, augite, hematite and mullite. The predominant peaks are associated with quartz and minor are cordiorite, crystoballite pyroxene, mullite, *etc*. The crystalline phases identified are in agreement with the results observed by XRF shows in Table-2.

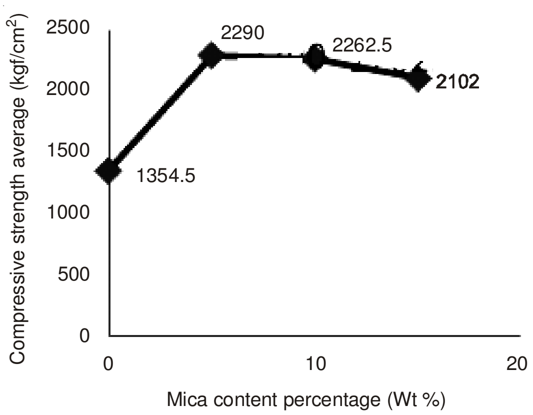

Fig. 6. Effect of mica contents on compressive strength

DTA/TG curves of brick with mica addition are shown in Fig. 8. Generally, the diagrams represent three peaks; two endothermic and one exothermic. The first endothermic peak (100 ºC) is due to the sample hygroscopic water lost and is associated with a 7 % of weight loss. Here the sample becomes dry. The second peak at 820 ºC is due to the destruction and dehydroxylation of the clays and recrystalization into meta clays with a weight loss of 17 %. It can also associate with calcite and gypsum demolition and volatiles like CO_2, *etc.* release. The exothermic peak at 900 ºC is due to meta clay decomposition to form other phase like Al-Si spinel, mullite, aluminosilicate and SiO_2 liquid phase. This result agrees with the XRD and XRF data's actually. Namely the sample becomes dry till 200 ºC and from 200-900 ºC the organic matter were oxidized and the minerals like calcite, gypsum, clays and specially mica were decomposed and unstable and also the gases and volatile released. The pulsation in 400-600 ºC is due to allotropic transformation of α-form to β-form, for example in quartz with no weight loss[16,17]. Fig. 9 shows the process of clay revolution along with increasing temperature[18].

Conclusion

The utilization of mica mineral powder as an additive in industrial brick production has been the objective of this study and investigated the influence of chemical and physical properties of fired clay brick at different type of mica powder contents. The results for this study show that 5 % by weight of mica powder can be added to an industrial brick mortar with increasing properties of the final product and developing their physical and mechanical properties. The considerable point

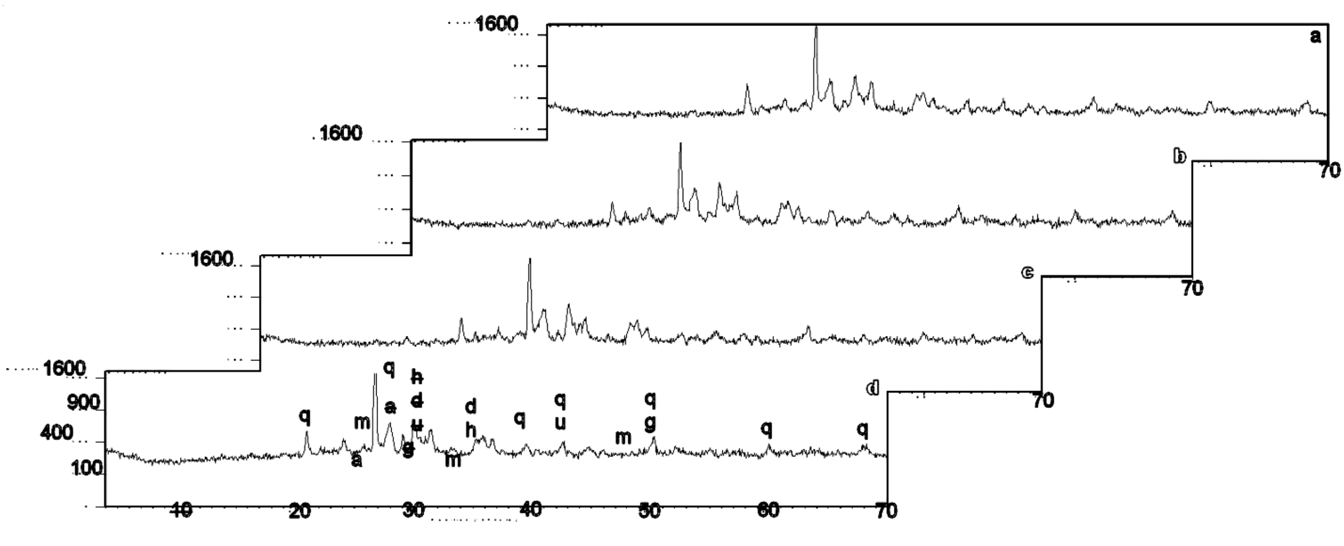

Fig. 7. XRD pattern of fired bricks with different mica content percentage; a control sample; b brick with 5% wt mica: c 10 % wt and d 15 % wt mica contents. Q as quartz, A as albite, G as gehlenithe, H as hedenbergite, D as diopsite, U as augite, M as mullite

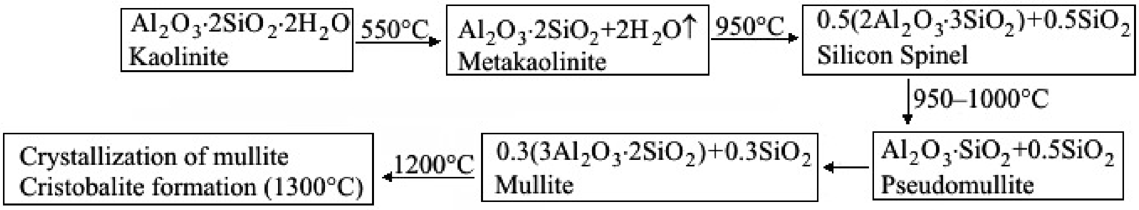

Fig. 9. Sequence of solid state reactions due to kaolinite transformations during thermal treatment [Ref. 18]

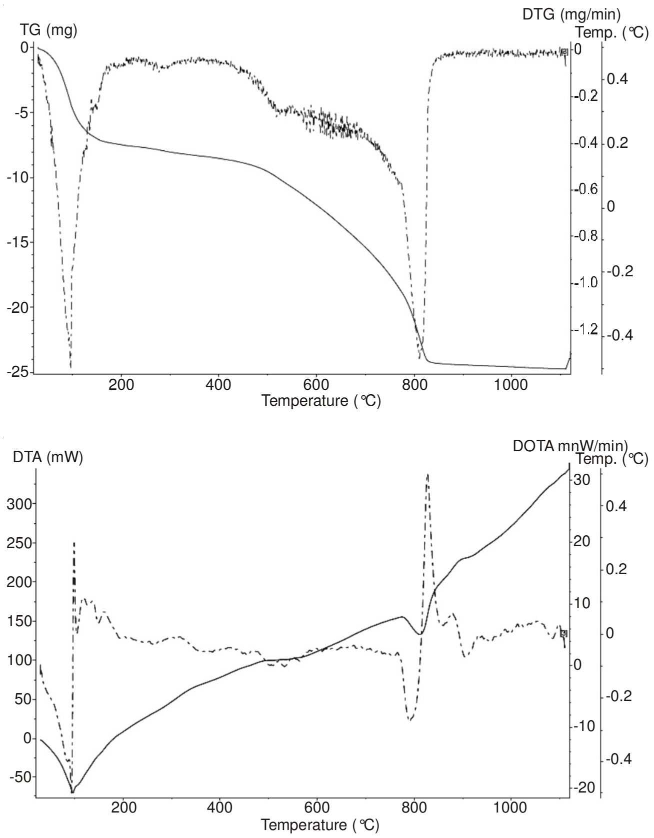

Fig. 8. DTA/TG curve of the sample with mica additions

of mica additives to raw material is compressive strength increasing up to 68 %. It can be significant in building resistance against the earthquake and other environmental pressures. Of course, the unfavourable parameters like water absorption increased but they are all in standard range. As regards all parameters, we suggest that 5 % wt mica added to raw bricks mortar could be suitable. And also the inactive local mica mine can be reopen.

In conclusion, with increasing demands of the construction industry, bricks quality and job become more important day by day in Iran. This study has significant important role on the increasing the quality in the brick production along with a great contributions to economy and making local jobs for habitance.

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