GENESIS OF SHADE-VARIATION IN CERAMIC-TILES AND SOME SUGGESTED REMEDIES

"SHADE AND SIZE VARIATIONS ARE INHERENT IN ALL FIRED CERAMIC PRODUCTS; SHADE AND SIZE VARIATIONS BOUND TO OCCUR : MIX WELL BEFORE USE"

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The above two captions are encountered on the cartons of some of the most well-known tile manufacturers of the world - whether from Spain, Italy, Germany, UK, Brazil or even a developing country like India. Depending on the outlook, these variations are considered as properties, characteristics and/or defects.

Because of these inherent properties (the writer prefers to use the term properties rather than the term defects) a certain set of tolerances was evolved by different countries/group of countries like BS, ASTM, DIN and then for ceramic tiles the European standards or CEN Standards. Interestingly whereas most other properties were quantified and their tolerance limits specified, there was no standard mentioned for shade-variations or otherwise for obvious reasons of the personal equation involved. What is considered as a ghastly or unacceptable shade- variation by one individual is often raved about as a thing of beauty by another. Another most pertinent point here is the quality of laying which can make a uniform colour of laid tiles look more insipid than cheque-red paint or on the other hand, can make even widely differing shaded tiles of the same colour give the get-up of a pleasant and harmonious whole even though no TWO TILES MAY BE EXACTLY ALIKE. The tile layers can thus make the world's best tiles look shoddy or can elevate second rate tiles to a position of admiration by their laying.

CONTRIBUTION OF PIGMENTS:

Perhaps the first and foremost and also the most important contributor to shade-variation can be the ceramic pigment itself. From the writer's experience in a ceramic glaze and colour manufacturing company, it is well established that batches of the same colour system often vary in a certain range of intensity and sometimes even tonality. These batches then have to be "corrected" (diluted or concentrated or adjusted as the case may require) to bring them to the sales standards. It would therefore be advisable to have a very close rapport between the customer and the glaze manufacturing company in such a manner that either the glaze manufacturer maintains a large stock of standard colours for a particular customer or depending on the economic compulsion and situation of the customer, the customer can maintain large stocks of the standard pigments for use. Needless to

mention it might even be advisable for the customer to once again reblend different supplies of the same pigment from the same supplier to have constancy of shade over a long period of time.

CONTRIBUTION OF COLOUR GLAZE :

To ascribe shade-variation in tiles to improperly formulated or applied coloured glaze would be an oversimplification. Even with the same colour glaze and using the same application, tiles are found to vary noticeably and widely when fired through the same kiln. In the writer's experience at Johnson Tiles in India - to avoid shade-variations as far as possible - the coloured tiles were fired only in certain positions in the cross section of the Tunnel-Kiln i.e., in the interior and top outside positions only. This in fact entailed a very tedious Kiln car loading involving a lot of additional manpower and still Johnson's went through the rigmarole of segregating these positions for coloured-tiles firing. Moreover the point under discussion refers to a two- firing process which is supposedly more stable than single firing, in any case. Even with these extensive precautions, shade-variation complaints poured in everyday as a routine regular feature.

Without doubt, the single most contributing factor is the composition and the compounding of the coloured glaze. The composition of the coloured glaze should be so selected that it has a ceramic stability - that is to say that with minor variations in temperature or kiln atmospheric conditions, the colour should not alter its basic tone. Broadly speaking, coloured glazes made out of stabilized ceramic stains or colouring oxides are naturally more stable than raw oxides. Thus glazes using say iron oxide, manganese dioxide, copper oxide etc. would tend to be more unstable than glazes using stabilised stains or oxides (eg. off-white, tan and browns which are made using iron oxide and manganese in addition to stains are definitely more unstable than pink, grey and Zi-Si-Pr-V green which use only stains and no raw metallic oxides - Other Things Like the Background Colour & Application Being Equal). However, it is a matter of good luck that at least in the case of brown these differences in shade blend very well to give a pleasant overall get-up. Another very redeeming feature in the case of sprayed brown is the highly coloured background glaze having almost 6 percent stains to form a Yellow Base. In the context of composition and compounding, for a Company of some standing, it would be advisable to purchase a very precise electronic balance for the weighment of stains. This balance could be of 50 kg capacity with an accuracy of 0.0% or 5.0 gm. This would ensure the elimination of one of the most fundamental variables viz., accuracy of compounding.

From the materials-used-for-compounding viewpoint, it would perhaps be the logical corollary to replace Iron Oxide, Manganese Dioxide, Copper Oxide etc., with stable Ceramic Stains as far as possible to obtain the same shade in the coloured glaze. Though this would involve fundamental and time-consuming R & D the efforts have to be initiated at the right time.

Furthermore, to have a homogeneity over a large number of batches of coloured glaze, it would be advisable to make coloured-glaze batches as large as possible particularly for spray glazes. In fact, the best would be to blend about 2-3 tonnes of the coloured spray glaze in the dry state and then 100-200 kg. batches from this MASTER-BATCH could be ground out and used depending upon the needs. This would also nullify the effect of variations in the individual constituents of the coloured glaze eg., the stains and the carrier glaze itself.

CONTRIBUTION OF THE BACKGROUND :

Needless to emphasize, the background itself (comprising of body plus frequently and engobe and the white or coloured base glaze, for spray colours and a highly opacified coloured glaze for unit colours or TINTE-UNITE. Changes in the body colour occur because of a variety of reasons, the most important being changes in the chemical composition of the body constituents. Perhaps in the case of a red MONOCOTTURA body, the single most important constituent is iron oxide which contributes to changes in the colour of the body. It is necessary to qualify this statement very emphatically with, "OTHER THINGS BEING EQUAL" for the simple reason that sometimes because of a sudden increase in the silica or alumina content of the body (which is evidenced by the high temperature differential between top and bottom temperatures to obtain a flat tile) the colour of the body becomes light- coloured and the water absorption is higher even at high temperatures. The other possibility

is that the iron content in the iron-bearing clay goes down (which can be subsequently confirmed by chemical analysis) as a result of which the alumina and silica go up proportionately.

Hence to ensure a constant chemical and mineralogical composition of the body, it is necessary that materials are blended in a few thousands of tons, at the mine head itself or at the supplier's end. The ideal situation would be to have captive mines of body materials required by a company particularly in the absence of reliable suppliers/mine owners. This would however entail a fair amount of capital cost particularly for the blending equipment eg. earth movers, bulldozers, chain and other shovel loaders and blenders. Alternatively the tile manufacturers would have to finance/enter into contracts with large suppliers/mine owners to make the expenditure cost-effective.

As an automatic corollary of the preblended material, adequate for 2-3 years production, would be that the kiln temperatures both top and bottom would remain reasonably constant over a long period of time to obtain the same water absorption, flatness and size and would have a salutary effect on quality by the consistency of colour within reasonable limits, if the glazes have been properly and accurately compounded.

CONTRIBUTION OF THE ENGOBE :

The engobe is an intermediate layer used in a single firing process adopting the red or off-white body and occasionally even for white body to mask the colour of the body and also to serve as a protective refractory intermediate layer which would suppress evolution of gases and prevent defects like pitted surface of the glaze and pin holes etc.

Although the engobe can never completely mask the colour of the body it would be most desirable from the point of view of minimizing shade-variation to have an engobe which is as high in opacity and whiteness as possible. This would obviously imply the highest possible usage of a white burning ball-clay like WBB's BWS-SP and Bitossi's Zircobit MO. In fact even the frit can contribute to a large extent to the opacity and whiteness of the engobe and hence is desirable to use such a frit as a component of the engobe. To put it in a nutshell, only high opacity engobe should be used to minimize shade-variations caused by minor changes in the shade of the body. It would not be out of place to emphasize that the coefficient of the thermal expansion of the engobe frit and clay should be very carefully and thoroughly evaluated before compounding the engobe to prevent uncontrollable bending characteristics of the fired tile because of the antagonism in the dilatation between the body and the engobe.

CONTRIBUTION OF THE BASE GLAZE :

With the whitest of engobes, the opacity of the base glaze itself still has a stellar role to play in contributing to the shade- variation. From the writer's experience the following example can be cited:

On account of the high incidence of Import Duties on glaze materials coming into India, intensive development was undertaken by the writer - using the writer's past experience in Ferro-India to develop a white base glaze as an undercoat for spray colour and as a carrier for the TINTE-UNITE. A substitution of the Italian frit by an equivalent Indian frit, which developed low opacity in the final glaze, gave tremendous problems of shade- variation, both in "SPRAY COLOURS & TINTE-UNITE". The raw mineral additions substitution by Indian materials in conjunction with the Italian frit did not however cause such major problems. It would be pertinent to emphasize here, that the single most important constituent is the quality of the Zirconium Silicate which can make or break the quality of consistency of shade of the final glaze, be it white or coloured. Hence only a high quality opacifier like Zirco-bit MO or Zircosil should be used.

Although in the Indian context (because of high Import Duty) the engobe and base glaze formulae should be so selected as to use minimum quantities of imported materials, it should be clearly understood and appreciated that no price is heavy enough to pay to enjoy a pride of place in the market as the BRAND LEADER. Hence unless the economic compulsions of the Indian tile industry in general and/or a specific tile manufacturing unit in particular warrant otherwise, one should not

hesitate to use the highest quality frit and the opacifier from imported source to have a high quality glaze and thus avoid variations.

CONTRIBUTION OF THE ENGOBE AND GLAZE APPLICATION:

Once a satisfactory engobe and glaze system has been developed, -to maintain constancy of application-, the density of the glaze and the pick up weight on the tiles has to be constantly monitored. However, in very hot weather, particularly in tropical countries like India, these two parameters have a tendency to change at much shorter intervals. To counter the effect of quick drying-up the quantity of CMC can be increased by about 50% in the summer season. CMC is known to retard the rate of drying and also controlling to an extent, the occurrence of pin-holes. The viscosity of the engobe and the glaze also needs to be maintained very stringently in a narrow range to have the correct surface application, which can also at times appear to alter the shade of the colour. Certain flexibility as regards the application however has to be kept to obtain smooth surface or avoiding pock- marks.

As a further improvement of the procedure of checking of weights periodically, a highly accurate electronic balance like the Mettler PM-4600 can be used and which can be hooked to a centralised laboratory computer and recorder so that the weights can be monitored continuously even on audit basis by the central laboratory.

Since the final colour that the human eye sees is a cumulative sum-total of all the applications viz. engobe plus base glaze plus spray colour (when used) all of them have to be monitored frequently and accurately. The most critical application quite obviously is the colour glaze application which has to be controlled very accurately (using the type of electronic mentioned earlier). The density of the colour glaze also plays a very crucial role in the intensity and surface texture of the final colour.

While on the subject of spray colour glaze application, it would be most relevant to make a mention of importance of both quantity and quality of compressed air. In the absence of a separate compressor or a receiver/reservoir of compressed air for the spray cabins, even with a uniform flow of spray glaze, the application varies whenever other points using compressed air draw the same from the line. This variable though not critical, does after all contribute to the cumulative effect. The solution would be to have a separate compressor for the spray cabins and/or a large receiver/reservoir which would ensure both the requisite pressure and quantum of compressed air.

As regards the quality of compressed air there can be no two opinions that the compressed air should be completely free from water and oil (this is in fact a requirement for all hydraulic and pneumatic systems in a good ceramic tile plant for the longevity of costly equipment like presses, pneumatic controllers and even pumps like spray-drier's, roller cleaning m/c etc.)

At the cost digressing a little bit -just as was discussed under the heading of the body materials, similarly for engobe, base glaze (whether white or coloured) and spray glaze as well- it would be of great advantage to have storage tanks of 8-10 tonne storage capacity for engobe plus base glaze and about 2 MT tanks for spray glazes so the changes in a batch of glaze get diluted by the previous stock present. Even from the stand point of a buffer stock this would stand the user in very good stead, in case of break down or relining of a ball-mill.

ROLE OF FIRING:

The proverbial acid-test in the case of ceramics is the firing test. The final operation of firing can make or break the entire effort put in till that stage.

The cardinal principle in the case of a single-firing process is to maintain the size and flatness of the tile. In trying to achieve these desirable characteristics, very often the temperatures are so adjusted as to cause a variation in shade of the colour being fired. Firing is the operation where the interplay of the entire gamut of factors like consistent body raw materials, constant composition of body, correct compounding and application of glazes and quantity an quality of air come into play. Thus consistent raw materials but improperly proportioned can lead to variations in shade because

of the necessity of adjusting kiln temperatures to obtain a flat tile true to size within the acceptable range.

Similar statements can be made about any one of the other variables, any one of which when sufficiently varied with all other constant can cause shade variation. For example change in the application, with all other factors constant causes variation.

CONTRIBUTION OF SORTING

The normal procedure for sorting -especially with respect to tonality in the writer's experience- is to take the tiles unloaded from the kiln to a separate area and then sort them thoroughly against the Master Standards. Even in one particular colour, based on the tonality, it is common practice to have 2- 3 tonality shades which are segregated and sold as such to avoid mix-ups.

Lighting (type of illumination) both at the time of matching the shade by the glaze-man and at the time of sorting by the sorter should be exactly the same, failing which Grey can be easily mixed with White, Pink with Off-white and Ivory with Light Green and so on. The colours as seen in the artificial night-light appear completely different from those during the day.

Though included here under the heading-firing/sorting, another cause for constant but minor alternation of temperatures in the kiln is the composition of glaze and engobe and the quantities applied. To be specific, glazes using the higher dilatation coefficient engobes require completely different settings as compared to the lower dilatation coefficient engobes or mixed engobes. Moreover certain colours require definitely different carrier-glaze compositions, as a result of which their dilatation coefficients are substantially altered and consequently the kiln temperature settings have to be altered to make a flat tile of correct size. As a result of these setting changes, minor shade variations can and do occur in both the premium and the standard colours.

ACCIDENTS AND NEGLIGENCE

Last but not least is the operator's directly and ultimately of the supervisor and the production manager's, the responsibility to maintain densities and application weights of the different glazes. For reasons such as shortage of manpower, urgency for execution of certain order and sometimes even negligence, the density and application change markedly causing shade variation. Very often because of choking of spray guns, the application and pattern change completely and before the operator notices or realizes what has happened, a few square meters have already gone into storage car, leaving no option but to fire it. The onus of rectifying the situation then rests with the sorting in-charge to segregate them. Sometimes in a situation like this, colours like flamed grey would have a few rows of plain white which would get mixed in them in the absence of sufficient vigilance which would have to be minimised to the extent humanly possible.

SUMMARY

To recapitulate and summarise the points that have been discussed so far, SHADE VARIATION although an INHERENT property of all fired ceramic products, can be controlled to within acceptable limits by ensuring the following:

A) PREBLENDING OF LARGE BATCHES OF COLOURED GLAZE FOR SPRAYING IN LOTS OF 2-3 TONNES. CAN BE DONE AT SUPPLIER'S END OR BY THE USER IN A SEPARATE SET-UP. THIS WAY EVEN THE USERS COMPOSITIONS REMAIN PROPRIETARY.

B) PREBLENDING OF INDIVIDUAL BODY RAW MATERIALS AT THE MINEHEAD/ SUPPLIER'S END FOR 2-3 YEARS REQUIREMENT.

C) MAINTAIN A CONSTANT FORMULATION FOR THE ENGOBE AND THE BASE GLAZE, TO TAKE SMALL VARIATIONS OF THE CHANGES IN THE BODY COMPOSITION INTO IT'S STRIDE. IDEALLY WE SHOULD USE COMPLETELY OPACIFIED ENGOBE AND BASE GLAZE INCORPORATING THE BEST FRITS, PIGMENTS AND OPACIFIERS FOR THE PURPOSE.

D) REFORMULATE THE COLOUR GLAZES TO EXCLUDE RAW OXIDES LIKE IRON OXIDES, MANGANESE DIOXIDE FROM OFF WHITE, TAN & BROWN FORMULATIONS AND COPPER OXIDE CHROME OXIDE FROM GREENS. THIS SOLUTION WOULD NATURALLY NOT APPLY FOR "SPECIAL- EFFECTS".

E) MAINTAIN A VERY ACCURATE WEIGHING BALANCE FOR WEIGHMENT OF COLOUR OXIDES AND STAINS, OF 0.01% ACCURACY.

F) PUT ADDITIONAL MANPOWER ON THE GLAZE LINE SO THAT THERE IS ALWAYS ONE MAN CONSTANTLY ON ONE GLAZE APPLICATION BOOTH.

G) USE ONLY HIGH QUALITY OPACIFIERS LIKE ZIRCO BIT-MO AND ZIRCOSIL FOR BOTH ENGOBE AND BASE GLAZE.

H) REFORMULATE SPRAY GLAZES FROM THE APPLICATION STANDPOINT TO HAVE AN APPLICATION RANGE 3.0 TO 3.5 GRAM PER 20X20 TILE IN TWO PASSES.

I) RECORD FAITHFULLY DENSITY AND APPLICATION OF ENGOBE, BASE GLAZE AND SPRAY COLOUR EVERY 15 MINUTES AND ADJUST IMMEDIATELY. SAMPLES SHOULD BE AUDIT CHECKED BY LABORATORY AND MANAGER.

J) INSTALL A SEPARATE COMPRESSOR/RECEIVER FOR SPRAY-BOOTHS FOR WATER AND OIL FREE COMPRESSED AIR.

K) REFORMULATE ALL GLAZES TO HAVE A COMMON BASE GLAZE COMPOSITION AS FAR AS POSSIBLE SO THAT FIRING CHARACTERISTICS REMAIN THE SAME. THIS WOULD NATURALLY NOT HOLD GOOD FOR SPECIAL COLOURS, REQUIRING SPECIAL BASE GLAZE FOR THEIR DEVELOPMENT.

L) HAVE STORAGE TANKS OF 8-10 TONS CAPACITY FOR ENGOBE AND BASE GLAZE AND OF 2 TON CAPACITY FOR SPRAY COLOUR.

M) MAINTAIN KILN CONDITIONS TO MINIMUM TEMPERATURE VARIATIONS BY RUNNING ONE TYPE OF GLAZE OR COLOUR CONTINUOUSLY OVER A LONG PERIOD OF TIME.

N) HAVE LIGHTING ARRANGEMENT SIMILAR TO DAYLIGHT AS FAR AS POSSIBLE AND AVOID CHANGING OF COLOURS ON THE GLAZE-LINE AT NIGHT. ALSO HAVE A SEPARATE AREA FOR SORTING FOR DECIDING ON TONALITY AND SHADES. GROUP STANDARD COLOUR INTO 2-3 SHADES.

O) MAINTAIN ADEQUATE SPARES OF SPRAY GUNS AND THEIR PARTS LIKE NOZZLES ETC.

P) MAKE LARGE RUNS OF ANY COLOUR AT A TIME BATCH SAY, 2-3 DAYS PRODUCTION.

Q) SELECT THE PIGMENT SUPPLYING COMPANY FROM A COLLECTION OF THE BEST IN THE MARKET SO THAT LOT-TO-LOT VARIATION IN THE PIGMENTS ITSELF IS AVOIDED. IT WOULD BE PREFERABLE IF THE SUPPLIER COULD MAINTAIN A LARGE INVENTORY OF STANDARD COLOURS SO THAT VARIATION IN SUPPLIES IS NEGLIGIBLE.

Although implementation of the above points would cost a company a tidy sum of money, it would be money well spent, probably as well or better than the advertising budget. Strategically and perhaps from the liquidity view point certain retrograde steps like using inferior frits, colours and opacifiers may have to be taken from time to time because of economic compulsion. But once we have received good returns we should plough back these returns in the interest of quality and consistency which will make any ceramic company a force to reckon with on the international scene for all times to come and progressively improve and consolidate its position till it is indisputable NUMBER ONE.