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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF CEMENT AND BUILDING MATERIALS

OPPORTUNITIES FOR TECHNICAL CO-OPERATION BETWEEN DEVELOPING COUNTRIES FOR PRODUCING BUILDING MATERIALS

Background Paper

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OPPORTUNITIES FOR TECHNICAL CO-OPERATION BETWEEN DEVELOPING COUNTRIES FOR PRODUCING BUILDING MATERIALS

by

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ABSTRACT

Existing appropriate methods being used are described and technological gaps are identified in some examples from processes related to the manufacture of building materials at the simplest levels. The processes and materials covered include small scale surface mining methods, pozzolanas, concrete blocks, clay bricks and tiles, lime kilns and small scale cement plants.

The conclusion is drawn that all of these should be considered for inclusion in the TCDC work programme. It is recommended that details of the present methods in use have to be recorded now and made available to regions that should adopt them. In the industrial nations there has to be re-examination and modification where appropriate of the designs of the best of the earlier equipment. The information should be re-published by their technical journals for the benefit of the small scale industries overseas.

CONTENTS

1. INTRODUCTION

Of the four main objectives of this Forum, this paper is intended to be a contribution towards achieving three of them as they apply to the rural requirements of building materials such as cement, lime, blocks, mortars, clay bricks and tiles and including also the surface mining of their raw materials and similar industrial minerals.

The paper will mention six areas where there are processes that would benefit by the application of alternative techniques. It will make some policy proposals for assisting in the development and application of appropriate technology. It will also suggest what has to be done to obtain greater international co-operation and outline two directions for study, one in the industrialized countries and the other in the developing nations, which so far seem to have been neglected.

The level of technology under consideration by this paper is mainly the simplest. In other words, that which would be used by, for example, pioneer settlers in remote regions, transmigrants, refugees and inhabitants of rural areas that have become devastated by earthquake or flooding. This implies manual methods initially with the introduction later of simple powered devices.

An attempt is not made to cover the whole building material field nor to present an in-depth examination of present methods. Neither are there proposals for a complete plan of action. There are organizations such as VITA, ITDG, etc., which are more capable of doing this. The suggestions made in this paper can be only a part of what should be done because they are based on observations made in a few countries and only during the past six years. Someone else has to see how they might fit in with other proposals being put forward.

It is apparent that already there are many investigations being made into alternative techniques, by a growing number of appropriate technologists at centres set up in the industrialized and developing countries. A main theme in this paper is that the results of the work done so far now have to be reviewed. This would be by a competent world body who would determine which designs and operating procedures are able to be proven as the best for the particular circumstances in the areas of the world where they would be used. Then it would be for the U.N. to publish the methods in a manual so that it could be more certain that the methods being demonstrated and adopted during field training sessions were the most appropriate available at that time.

2. SMALL-SCALE SURFACE MINING METHODS

The digging of near surface deposits of non-metallic rocks and minerals is a common activity in rural communities. It provides the raw materials for building material production and include clays, limestones, gypsum and natural pozzolanas and also other materials such as bentonite, kaolin, diatomite and silica sands.

It is done manually by men working in pairs or small groups, usually family relatives who have, or claim, the traditional right to work a certain place whose area may be less than 100 m^2. An exposure of marble, for example, in an area about 100 m by 50 m had as many as four 'owners'.

Operation of the quarry is either by digging horizontally into deposits which have become exposed by the side of rivers or roads or by digging down vertically to reach a seam which is covered by an overburden that may be several metres thick. In each case it is the presence of the overburden and its disposal that causes most of the problems that will be mentioned.

Responsibility for development of the small-scale non-metallic mining sector is not necessarily with the Ministry of Mines but may come under the local provincial office of the Ministry of Home Affairs. In that case there may not be staff there who have the training for giving advice to the miners. The assistance needed, though, is not so much technical as organizational.

2.1. Problems with Present Procedures

Due to ownership of the land or its mining rights being with several people, many independent operations develop on the same deposit. The problem is how to co-ordinate the various groups and so overcome the following difficulties:

- much raw material is never reached because it becomes covered with overburden dumped around the periphery of the several pits that are dug.
- failure to remove the overburden in a systematic manner

- causes it to fall into the workings and contaminate the mineral. This is especially significant in the digging of silica sands as glassmakers must receive material of non-varying quality.
- the worked area is left in a disrupted state without restoration of the ground for agricultural use.
- the progressive digging creates high, steep cliffs which become unsafe and fall on the miners working beneath them.
- water accumulates in the rainy season so that mining, and the industrial production dependent on it, have to stop for several months.

2.2. Suggestions for Improving Working Methods

If the Government decides that co-ordination of development in the industrial mineral sector is necessary for it to keep up with the pace of national industrial development, then the ministerial responsibilities for small-scale mining of raw materials for the building and ceramic industries, etc., have to be defined. Whichever Ministry is put in charge, it has to have provincial offices and staff who are prepared to work in the field to demonstrate the appropriate method of mining and advise the local people on how to set up a co-operative system.

The geological survey should indicate where mineral is likely to extend to and supervise digging of test pits and shallow bore holes, if deemed necessary.

Whatever administrative organization is created, it has to be staffed by trained personnel who will demonstrate in the field, by diagrams and lay-outs over the area of the deposit, how removal of the overburden and raw material should proceed. There are many advantages to co-operative mining systems but, as with all such schemes, the benefits will not be gained if the character of the local people is not conducive to working well together. The many advantages have to be spelled out at meetings of all the miners. They include safer conditions, better quality product and being easier to obtain loans for purchase of equipment, both for mining and up-grading the mineral.

The subject of small-scale mining is one highly suitable for the TCDC programme as the recommendations they come up with would be applicable wherever the deposits occur irrespective of the region.

3. POZZOLANAS

These are materials on which already there has been much work done by laboratories in many countries and especially, of course, here in India. No doubt there are other contributions during the Forum which will cover this subject more fully. It seems to be time that someone assessed the findings of the laboratories as well as the procedures in use and, through TCDC or UNIDO, draw up and issue proposals for the appropriate processing and utilization of pozzolanas.

They are very suitable for development in the developing countries as they are fairly readily available in Central America and the Andean countries, parts of Africa and South-East Asia as well as several of the small oceanic islands. These natural pozzolanic materials, when mixed with lime, should make a mortar which is cheaper than one made with Portland cement yet being perfectly suitable for much of the kind of building work done in rural areas. This topic will be dealt with in Section 7.1. where the properties desirable in a'rural cement' are discussed.

Similarly, clays and shales which, when burnt at a moderate temperature of around 650 to 800°C, form artificial pozzolana are also of widespread occurrence. Some, however, are more suitable in this respect than others.

This paper will mention just two processes which should be adopted more widely than at present.

3.1. Pozzolanic Cement from Volcanic Materials

Unfortunately there seems to be too much prejudice in favour of Ordinary, Type I, Portland Cement (OPC). Firstly, it is being used in situations which do not call for its good property of comparatively rapid development of high strength. Secondly, it is being specified in projects which need relatively low heat of hydration, good resistance to sulphate bearing and acid waters and yet where the strength will not be put to the test until after many months when the project is nearing completion.

Such situations include certain marine structures, e.g. docks, massive foundations and dams, irrigation canals, etc.

By grinding about 30% of pozzolana with Portland cement clinker, a Pozzolanic Cement is produced. The pozzolana can be volcanic ash, or tuff, and pumice and also diatomaceous material. The Pozzolanic Cement normally costs less to make than does OPC but, unfortunately, is not always sold at a lower price. One can sympathize with the manufacturer who, rightly, can claim that it is a better cement for many customers.

A further reason why this cement is suitable for use in developing countries is that many of them have quite high ambient temperatures. This will accelerate the reaction between the pozzolana and the free lime liberated from hydration of the clinker minerals. Apart from two extra silos, for the pozzolana and the finished cement, little extra construction is needed at the cement works. As mentioned in Section 7.2., a preferable alternative policy is to transport the clinker in bulk to separate grinding mills at which it is mixed with the pozzolana. These will be at sites carefully selected in relation to the market and the deposits of volcanic ash, etc.

Besides having to overcome the conservatism of the customers in the construction and building industries, the other problem for the potential producer of Pozzolanic Cement is to find deposits of pozzolana which are well located, large enough and sufficiently uniform in their composition and pozzolanic 'activity'. This again is where the geological survey should not overlook the non-metallic rocks and minerals during its work. They have to sample, and evaluate in co-operation with a building materials institute if there is one, the pozzolanic activity of the various volcanic deposits that are finely powdered or are easy to grind.

3.2. An Artificial Pozzolana for Rural Building Work.

By the time a bag of Portland cement arrives, assuming it survives the journey, at a village on a remote island or in a valley high in the mountains, the price for it will be so high as to dissuade the local people from buying it. Production of lime, on the other hand, is very much a rural industry and,in comparison with the bag of cement, the lime should be available locally fairly cheaply. If the lime making operation can be combined with making an effective pozzolana from locally available clays, then the villagers have at their disposal the constituents for a low cost binding material for use in mortars for building walls and irrigation ditches, etc.

The method described briefly here is that used in a few kilns in parts of a country in South-East Asia and, no doubt, it is done in some other areas. As the practice is not known in at least three South American countries, possibly the simple procedure should receive wider notice.

Clay, similar in nature to that used for brick-making, is made into round balls approximately 10cm in diameter and allowed to dry. They are then placed in a layer, three or four deep, on the top of a traditional, batch-fired lime kiln which has been charged to the top with lime-stone. As the limestone is calcined, the heat escaping at the top of the kiln passes through the 'mud pies' and bakes them at a moderate temperature. This is sufficient to activate the clay minerals present but not enough to develop a ceramic bond. It is not difficult, therefore, to break up and crush the baked clay and this was done simply by placing it on the ground and beating it with a stick.

This pozzolana was used,mixed 1:1 by volume with hydrated lime, for bonding together stone blocks in a wall. In another case, a 1:1:2 mix, hydrated lime : pozzolana : sand, was applied as an exterior rendering to the side of a public meeting house. In both cases the result being obtained was satisfactory.

It is useful to try and compare the costs for this village binding material with the price of OPC at the time (January 1977), in equivalent US dollars:-

Pozzolana(selling price)	: $3.85 per m^3
Hydrated lime " "	: $12.00 " "

Therefore cost of the
1:1 lime-pozzolana mixture : $8 per m^3

A typical price for OPC in bags from a village shop in that country at that time was equivalent to:

: $114 per tonne (metric)

At a bulk density of 1450 kg/m^3, the equivalent price for 1 m^3 of OPC was: : $165 per m^3

The OPC would be used in mortars such as 1:1:6, OPC:lime:sand, or 1:4, OPC : sand. Taking the latter, and ignoring the cost of the sand, the cement mortar cost becomes about a fifth of the cost of the cement, or:

: $33 per m^3

This is four times more costly than the mortar made with local materials. It is likely, then, that there is scope for making worthwhile savings in rural building costs by the introduction of processes such as this for making alternative cements.

4. BLOCK MAKING

Small-scale production of concrete blocks not only provides employment to families in rural areas but also is a stepping-stone to the establishment of a factory making a whole range of precast concrete products. This chapter deals with the importance of using well proven methods for block making, especially at the beginning, and being very careful before deciding to use imported automatic machines.

4.1. Problems with Automatic Systems

Six years ago there appeared in a European journal on precast concrete products an article entitled: " Clean and Manless Factories ". However, it did say that at least one man was required, although he could supervise the running of two 500 tonne hydraulic presses together making around 4000 paving units in one shift.

The introduction of far less automated methods than these in the poorer and lesser developed countries can be full of problems for the precast concrete products manufacturer, even with the process of block making alone. This is because the machinery nearly always has to be imported and its operation, servicing and repair requires much skill and workshop facilities. The quality of the products tends to be very sensitive to small variations in the physical characteristics and proportions of the raw materials and this results in a high percentage of broken or low quality blocks, etc. In addition, of course, there is a high initial capital expense.

In the author's experience, the quality of blocks made using the simplest manually compacted or vibrated systems is as good as or better than that of the ' egg-layer' mobile machine producing up to nine or more blocks at a time. The 'egg-layer' requires a large flat area of concrete to be laid before production can begin and also a supply of electrical power. Where skilled personnel are not available but unemployment of fairly unskilled workers exists, the potential block maker will have a far less troublesome initiation to manufacturing if one of the two simple casting systems discussed here is used. These are suitable for selected mixes based on either a concrete mix, i.e. cement : sand : coarse aggregate, or a lime : 'trass', e.g. pumiceous tuff, mix. Blocks made with the soil : cement system require high moulding pressure. For these the well known CINVA - ram moulder, of the Inter-American Housing and Planning Centre of the Organization of American States, is appropriate.

Only the general outline of each device is given as variations within the overall specification exist. It is up to TCDC to prescribe the main design features after study of the best which are in use currently.

4.2. Moulding Using Hand Compaction

This apparatus is for regions where there is no electricity and no service or repair workshop. It makes one block at a time, compacted on its side. A common size, which might be adopted as standard, is 39 X 19 X 10 cm. By use of formers which are withdrawn before the block is demoulded, the product can be a hollow block having the advantages of lightweight and economy in raw material usage.

The mould and supporting frame are made of steel and the mould has demountable sides. Compaction is by exerting manual pressure on the filled mould by pressing down on it with a weighted flat steel plate. The height of the legs of the supporting frame are such that the operator works with the mould at a level which is the least tiring. As with hand moulding of bricks, productivity is much improved if there is attention to the ergometric considerations. Operators claim they can produce as many as 400 blocks a day although a somewhat lower figure is mentioned by their employers.

The device has to be able to withstand quite strong impacts with the compaction plate but should be light enough for two people to carry about the casting area. Appropriate designs of this type of mould exist in some developing countries including, for example, one that was being made in South America in 1975 and selling there then for approximately US$80.

4.3. Moulding with Vibro-Compaction

With this system hollow blocks are moulded in a vertical position, up to three at a time depending on block size. This is adjustable and typically 39 cm long by 19 cm high with a thickness of 10, 15 or 20 cm. There is normally a team of at least three people for preparing the mix, filling the mould, operating the machine and carrying the blocks, on a pallet, to their curing position.

The vibrator is belt driven and powered by either an electric motor or internal combustion engine. The production rate varies from 300 to around 1000 a day depending on the size being made.

In one South American country, the producers of lightweight blocks, using a mix of cement and pumice, had vibro-compacting machines that were being made in a small works located in a town high in the Andes. The equipment was claimed by them to be more satisfactory than the more expensive imported version. In 1975 the price mentioned for the local machine was equivalent to US$560.

5. CLAY BRICK AND TILE MAKING

There have been published various guides, and also kits are available, for starting up the small-scale production of burnt clay bricks and tiles. Although the overall process generally used is the same, there are local variations in both the designs used and the working procedures. In some countries it is normal to use horse power for pugging the clay, for example, whilst in others it is acceptable to trample the clay using the feet. In some of the latter cases, the beast of burden is the water buffalo and there may be problems in training such animals to carry out tasks which horses readily perform elsewhere.

Some of the traditional designs and procedures in use must be better than others. These and the ones being promoted by the various appropriate technology centres, should now be examined and tried out as part of the TCDC programme. Recommendations can then be made for the appropriate systems at each of three or more levels of technology, with modifications dictated by particular regional conditions.

The levels of investment and mechanization should begin at the cheapest and simplest, that is, with moulding entirely by hand power and using a clamp for firing. The higher technology level would have power driven extruders and cutting by wire and, for example, the utilization of waste heat from the kilns for drying. An important consideration is provision for firing by fuels other than wood which, in several regions, is becoming scarce.

5.1. Pugging.

This operation is usually performed inadequately and is the cause of breakages and poor quality in the products. A much more acceptable and effective method than using human feet is to use a small pugmill which can be driven by an animal or small watermill. The horse driven vertical pugmill is typical of the small brick and tile works in Paraguay and yet is not seen at all in some of the other countries in the same continent. It is constructed out of wood and has to be the right capacity for the strength of the animal. It is unfortunate that the well known 40 gallon oil barrel is slightly on the small side otherwise it might be adapted easily for building such a pugger.

5.2. Moulding.

The main defect of the traditional wet moulding method is that the bricks made are too shallow, around 4 to

5 cm, so that they crack across the middle and the brickwork needs the application of much more mortar as there are more joints.

There are several advantages to using a deeper mould, up to 7.5 cm, and filling it with a less sticky mix which is thrown in with some force rather than just poured in. This procedure uses sand for lining the mould and working surface. Drying is quicker and with less shrinkage. The bricks also have more regular dimensions.

5.3. Drying.

The newly cast bricks are often stacked in a way that leads to long and uneven drying causing a hold-up in production for lack of space in the drying shed and a greater incidence of distorted or cracked bricks, as well as tiles. There is much that can be done to overcome the problem by having a suitable stacking pattern and providing the shed with side flaps so as to adjust the flow of circulating air according to the direction and force of the wind, if any, outside.

At the higher technological level, drawings are needed by the entrepreneurs and Ministry of Industry field advisers for showing how to use the waste heat from the kilns. Calculations of the volume of air, temperature, relative humidity, etc., to dry a certain volume of bricks in a set time have to be simplified where possible and converted into the fans, motors and ducting, etc. that will be required for the construction of the drying system.

5.4. Clamp and Kiln Designs

Before a brick and tile maker in a remote area can construct his own kiln he has to supply his own bricks to build it with. It is, therefore, a basic skill to be able to construct a clamp, arrange the fuel and control the burning so far as it is possible.

The next stage is to know the design and construction of an up-draught kiln followed by the more fuel efficient down-draught and continuous kilns. For each of these types, and the clamp, appropriate designs have to be selected and then put in the hands of the people who will use them in the rural communities. At present this appears to be a task which the ceramic technologists in the Government institutions are not dealing with.

5.5. Fuels and Burners.

As mentioned previously, Governments of several countries are concerned at the loss of forested areas due to the cutting down of trees for fuel, especially in the firing of brick and lime kilns. The problem is present even in some OPEC countries and a switch to use of oil, gas, coal and agricultural residues is being called for.

There seems to be a paucity of information available in the field on the design of appropriate burners for these fuels. Those designed in the industrialized nations can be of too high a level of technology and are also too expensive. (These problems are discussed more in Section 6.1 dealing with lime kiln burners.) The burners and their controls have to be capable of manufacture, servicing and repair in the region where they will be used. This subject could also benefit from inclusion in the TCDC programme as some appropriate burners are already in use in various locations.

5.6. Lay-out

A well thought out arrangement for the factory, with provision of a properly designed table or moulding bench, contribute greatly to the overall efficiency of the factory and the comfort and individual achievement of the people working there.

6. LIME KILNS

A technological gap exists between the traditional 2 to 20 tonne a day, wood fired, batch or semi-continous shaft kilns and the 100 to 500 tonne a day shaft and rotary kilns used in industrialized nations. Attempts are being made to introduce continuous kilns, fired with fuels such as oil and to produce at least 10 tonnes a day of good, reactive quicklime.

The development work is going on not only at technical institutions in the developing countries and elsewhere but also the kiln owners are attempting to convert existing kilns from wood to oil as well as build and operate new types.

All the types in use and at the pilot stage should now be assessed and a manual written on the present 'state of the art ', with descriptions of the most successful so far in use. If it is found that an appropriate solution has not been reached, then the TCDC or UNIDO should instigate the further development work that is needed.

6.1 Existing Situation in Kiln Development

The traditional kilns produce lime relatively cheaply but they usually consume scarce wood and the product quality is often low. Their thermal efficiency is low as they operate either batchwise or semi-continuously. Individual operators are attempting to modernise their methods themselves but a common mistake is to locate the oil burners at or too close to the base of the kiln. The burners being tried by them produce a high temperature where the oil impinges on the stone instead of permitting combustion to take place deeper inside the kiln and with a softer flame.

The difficulty with development of shaft kilns, to burn oil or gas and give a higher output of better quality than the present kilns, is to build it at a low enough capital cost. In one recent case it was US$100,000 for a capacity of around 10 tonne a day. Taking depreciation into account it would not be possible to compete with the operations of the traditional kilns. In this particular case, a high proportion of the cost was for the burners which were to be made in Europe. In another case, the equivalent of US$27,000 was the estimate from a manufacturer in the EEC for a small mobile gas generator, fed by fuels such as coal, agricultural wastes or oil, for delivering producer gas to small batch kilns.

From this it looks likely that the solution has to be developed, and the kiln and all equipment built, within the developing countries to ensure that the costs for construction, repair and servicing are going to be feasible.

6.2. Outline Specification of the Appropriate Kilns

Two levels of technology are required. The first is for those kilns which will be located in remote areas. There would be available no electric power or specialized workshop facilities and help from national technicians only during the construction and commissioning, if then. The other is for kilns that might supply lime to builders in a large town or an industrial area. It would be within the reach of technical staff from specialised consultancy organizations and there would be electricity and skilled manpower available locally. There would be the need to achieve a product quality suitable for special markets.

The kiln for remote areas will operate continuously, fired with either mixed feed, oil, natural gas or producer gas. Output will be around 10 tonne a day.

As far as possible, the materials of construction must be only those available locally. Operation is manual and would make use of, whenever possible, the topography, such as a cliff face, for aiding the loading of the raw material and providing hydrostatic head for the oil flow to the burners. If refractory bricks cannot be made there then the alternative is to use selected natural stone. These and many other design and construction considerations would have to be listed.

The more advanced kiln will produce at least 10 tonnes a day, as quicklime, and its design will be suitable for scaling up to higher outputs. Its features will include power assisted charging of the raw material into the kiln, cycling of heat from near the top of the kiln to re-enter it at the calcining zone to effect fuel economy and devices for monitoring the burning process and facilitating its control. The kiln will have an exterior steel casing and be lined by insulation and refractory materials.

Such a project should include also an appropriate hydrator plant, operated during the day shift and capable therefore of hydrating at least two tonne an hour of quicklime.

7. CEMENT MANUFACTURE AT 20 TO 100 TONNES A DAY

The development of appropriate technology for small-scale production of Portland cement in least developed countries and regions has been reported on for UNIDO by one of its specialist consultants two years ago. The ITDG last year published an occasional paper dealing with the mini cement plants of China and the progress made in India by the Cement Research Institute. So there is no need in this paper to deal much with this subject. Three aspects of small-scale production, related to the conditions in rural areas, will be mentioned as a basis for discussion.

7.1. The Specification for 'Rural Cement'

There is the risk that the word 'cement' will be thought here to mean only Portland cement itself when in fact any relatively low cost hydraulic binder is being implied. This point is important, also, when introducing an alternative cement to a rural community. If it is called ' cement' and then found to have, as it surely will, lower strength development, there may be rejection of it and much subsequent difficulty in overcoming consumer resistance unless care is taken with its description and usage.

Ordinary Portland cement alone, mixed with sand, is not a suitable mortar for brick laying, external rendering and internal 'plastering' or much of the other rural building work in which the mix has to be 'plastic' or applicable with a trowel. To get sufficient workability the mix would have one part of cement to three parts of sand and this is too strong for general use.

Strength of mortars for masonry use need be only moderate and of greater importance are the adhesive and working characteristics. Neither is high early strength a necessity in mixes used for irrigation schemes. There, besides good adhesion and workability, durability against the the action of acidic, sulphate bearing or even relatively pure water is a main factor.

Therefore the specification of cements offered for rural use is more appropriately somewhere between that of Masonry Cement and Pozzolanic Cement. These are themselves based on Portland cement clinker but have the addition of around 50% of inert filler such as limestone in the former and around 30% of pozzolana in the latter. This leads to the second point.

7.2. Big Kilns and Small Grinding Plants

The policy adopted in many countries of introducing large capacity kilns in new cement projects is understandable in view of the various operating economies they offer, notably in fuel. Also, but of less interest to this Forum, there is their saving in manpower.

The point to note about the big kiln policy is that it does not provide the country as a whole with cheap cement. This is because of the added transport cost in delivering to far flung customers. (The exception to this would be a small country having good natural routes for transportation and a big construction programme).

However, big kilns do make cheap clinker and that is the factor that should be fully exploited but seldom is.

Whenever possible, cement should be transported in the form of clinker. This is done successfully for Singapore as well as the Canary Islands, for example. If there are deposits of materials such as pozzolana or even limestone located close to the point of discharge of the clinker at the distant island or valley in a mountain range, then they can be ground with the clinker and a little added gypsum in relatively small grinding plants. The local community then have the benefits of a local industry, making use of local materials to a significant amount, and, moreover, the cement will be fresh. The clinker can be kept for several months without much deterioration and so can be ground as and when required.

7.3. Europe Nearly 100 Years Ago

The shaft kiln originated in Germany. The two most popular of these introduced to England in the 1880's and 1890's were the Schneider and Dietzsch kilns.

The Schneider was said to be economical in both cost of construction and fuel consumption as well as being easy to operate. In 24 hr it could make 10 to 12 tons of clinker with the burning of 1.4 to 1.9 tons of coke. If it is assumed that the coke had a calorific value of, say, 9000 Kcal/Kg, then the fuel consumption was in the range 1260 to 1425 Kcal/Kg of clinker.

The Dietzsch kiln had even better fuel economy; 152 Kg of small bituminous or coking coal being used for 1 ton of clinker. Assuming a calorific value of 7200 Kcal/Kg for the coal, this indicates a fuel use of only 1080 Kcal/Kg of clinker. It was built usually as a pair of kilns from which the total output was 20 to 30 tons in 24 hr. The Dietzsch was also adapted and extensively employed for making lime.

For comparison, modern rotary kiln systems for cement have fuel efficiencies ranging from about 1575 Kcal/Kg for the wet process and down to about 820 Kcal/Kg for the semi-dry process, (Some suppliers of cement plants claim lower figures than these for their own systems). Thus, the fuel efficiencies of those old shaft kilns was not unacceptably high by today's standards.

Similarly, it might be worthwhile for appropriate technologists in the industrial nations to re-examine the performance and construction of other items used at that time such as grinding mills, as well as much of the other equipment used in the past at building material factories of all kinds.

Perhaps the answer to the question how to produce cement on a scale of around 20 to 100 tonnes a day lies in a combination of the best of the past methods and present ideas in the industrialized countries with the approach used by the Chinese but aimed at the needs of the rest of the developing world.

8. CONCLUSION AND SOME RECOMMENDATIONS

There are several subjects relating to the processes in the manufacture of building materials at the lower technology levels which should be included in development programmes of the centres for appropriate technology and entities such as TCDC. This paper has shown that there are many good designs and methods being used in some areas which are likely to be of use in other regions. It has indicated those fields, such as appropriate kilns for lime making and the small-scale manufacture of cement, where an appropriate answer does not so far appear to have been put into use.

Based on the points made in this paper, two lines of study are proposed which appear to have received too little attention. They could provide much useful information to the future appropriate technology projects of UNIDO and TCDC.

Those appropriate technology centres in the developing world should not overlook the wider significance of the methods being used there today by the small traditional industries, such as exist in the building materials sector. What may seem obvious or of little consequence in their own country may be highly appropriate for adoption in some other part of the world. Therefore, records must be obtained in the field of all the details of the processes being used there now. In some countries it is already too late to do this as, with the progress of industrialization, these appropriate methods have passed into the realm of the industrial archaeologist.

Those appropriate technologists based in the industrialized nations have the advantage of ready access to past records of the old methods used, especially those before the rise in wages and coming of automation which caused the disappearance of them in Europe and elsewhere. They can fill the gap that exists in the technical literature coming from the industrial nations which causes their journals to have so little significance for the people running small factories overseas, especially in the building and ceramic industries.

Thus, the old methods have to be re-discovered and re-assessed to see what aspects are still applicable to the developing countries. In particular, they could be improved upon by the inclusion of better working procedures and devices so long as the materials and skills for construction and operation are those present in the regions where they can still usefully be applied. Such a process of re-publication of the best of past technology could be a worthwhile contribution throughout all levels of technology, even up to that of a few years ago. Some of the brickworks in Holland, for instance, which have closed recently, are now appropriate for re-installation in other parts of the world.

SUMMARY

Findings are presented based mainly on observations made in the field by the author over the past six years in parts of South America and South-East Asia. The situation relating to the operations used in small scale production of building materials in rural areas is discussed and some of the problems outlined. The subjects dealt with are small scale surface mining operations, pozzolanas, block production, clay brick and tile making, lime making and the manufacture of cement for rural uses.

In mining, a co-operative system would overcome the present difficulties although organization of that, itself, could be a problem. More use should be made of volcanic ash and Pozzolanic Cement should more often replace Ordinary Portland Cement. Village communities can replace expensive Portland cement by a low cost mortar made in traditional lime kilns. Block makers should first buy nationally made moulds and vibro-compacting machines before considering importing automatic equipment.

Production of clay bricks and tiles has shown that some good appropriate techniques are available for pugging, moulding, drying, firing and organization of lay-out and working procedures. A technological gap seems to exist in the design of intermediate, oil or gas fired lime kilns and their burners. In small scale production of cement, the characteristics of the type of cement required for rural use

have to be specified. When feasible, small rural cement mills can make good use of the cheap clinker from large kilns at central plants and consume local raw materials as well. Designs of the old shaft kilns used in Europe are worth re-examination and possibly adapting for overseas installation.

All these are fields that might be useful to consider for inclusion in any future appropriate technology projects of UNIDO and TCDC.

Details of present methods used in all the developing countries themselves have to be recorded now before they are no longer used. Someone somewhere will always find a use for them.

The appropriate technologists based in the industrialized nations have the advantage of easy access to past records and old scientific journals. They should re-examine the previous designs for building material plants, up-date them by new appropriate devices and procedures and re-publish the information for the benefit of the overseas industrialists at all levels of technology.

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