A Critical Examination of New Constructional Techniques and their Influence on Productivity in the Building Industry with Special Reference to Housing in South-East Scotland

PART ONE      VOLUME I

by

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"For the structure that we raise
Time is with materials filled."
"The Builders"—LONGFELLOW

Thesis submitted for Ph.D.
1957
## PART ONE

( CONSTRUCTIONAL METHOD )

### VOLUME ONE

#### THE BACKGROUND.

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During the post-war years there has been an ever-ascending spiral in building costs, and growing concern about this has been reflected in the reports of nearly all the new towns development corporations in Great Britain. The increases in the cost of building materials have had much to do with this continuous rise in the cost of buildings, for example the price of imported sawnwood was more than six times as much in 1954 as it was in 1938 and cement has increased two-and-a-half times during the same period.

Other industries have had to contend with similar rises in material costs but have managed partially to offset them by means of a marked improvement in productivity through the use of new processes and techniques designed to increase efficiency. This is not to say that the building industry has not also achieved a higher standard of efficiency but it has not been nearly enough. In *1956 the output per worker in the industry was £1,373 against £556 in 1938, but because of rising costs the actual output was only about 60% of that achieved before the war.*

*"The Builder", October 12th, 1956.*
It has been estimated that during the next twenty years some six million houses will have to be built, and it is unlikely that conventional methods of house-building can provide this number of houses quickly and at a reasonable cost. The reason for this is that the great majority of the conventional type houses are erected by small builders whose experience, organisation and equipment are inadequate to operate the highly specialised modern constructional techniques that are rapidly becoming available to the industry.

The building and civil engineering industry consists of something like one million men employed by approximately seventy thousand firms. Of these firms only five thousand or so are equipped to apply and benefit from improved methods of construction, but it ought to be possible to increase this number quite considerably. One way of doing this is to see that the other 65,000 firms are made aware of current research work and experiments directed towards the achievement of improved productivity. At the same time it is important that the information on improved productivity should be linked up with actual cost-saving, for/


for improved productivity does not necessarily mean that final costs are reduced. For example, prefabricated components may be a means of improving output on the site but the cost of the process of prefabrication in the factory may absorb any savings realised on the site. Production must not be confused with productivity, for a low standard of productivity can be obscured by a high level of production that has taken up an excess of physical effort or mechanical power.

If improvements in the productiveness of the building industry are to be achieved - particularly with regard to the smaller and less efficient firms - it is clear that research and experimental data must be widely published in a simple and easily understood form, together with precise details concerning the actual cash saving resulting from the use of a particular technique of construction. Architects are growing more and more conscious of the cost-saving potential of the many new methods of building but they can rarely spare the time to experiment or to enquire deeply into the economic possibilities of these new methods. It is essential then that these research data should be widely circulated, not only throughout the industry but also throughout the architectural profession.

In/
In these notes which follow, an attempt is made in the first instance to sketch in the background to this investigation of the effect of new constructional techniques on productivity. Then in Vol. 2 a representative selection of new techniques is critically examined, and wherever possible the effect of the new method on productivity is discussed. In Part Two the aspects of productivity and cost are considered more closely by summarising the data already assembled in Vol. 2 of Part One, together with certain additional notes and analyses relating to productivity and cost.

The scope of this study is limited to constructional techniques and therefore does not take account of, or seek to enter into such fruitful fields of enquiry as site organisation and management, architectural design, etc. In the early stages of this study it was soon found that it would indeed be necessary to exercise some discrimination in the selection of suitable techniques for examination owing to the bewildering variety of new constructional methods now being applied in the industry.

Occasionally there have been instances where these enquiries have included a process which is not strictly a process/
process of construction. For example, the packaging of bricks has been discussed and also a number of mechanical aids to more productive building. Wherever possible, however, I have endeavoured to confine my studies to methods of construction.

The scope of this thesis was further limited by confining all study to new methods employed in house-building. This limitation was applied, firstly because the housing aspect of the building industry is worthy of a considerable amount of study and secondly because the field would otherwise have been much too large for any reasonable concentration of thought. Indeed, in the study of the many types of buildings which can properly be described as houses, the field has been wide enough and it may be that as a consequence of this, there has perhaps been slightly more emphasis on the two or three-storey type of house types rather than multi-storey flats.

It was intended that this study should have special reference to housing in South East Scotland because it was originally considered that there should be ample opportunity for site studies in this area. In particular it was hoped that a certain amount of time and motion study/
study might be applied experimentally to a pre-planned scheme of four-storey maisonettes to be carried out by the Dept. of Health in Edinburgh during 1955. These maisonettes were to incorporate a number of interesting techniques of cost-saving construction. It turned out, however, that the Dept. was not interested in my offer to carry out, partly as a College project, observations and cost analyses based on labour expenditure. This was in spite of the fact that the consultant quantity surveyor for this scheme had said that he would welcome my assistance in this connection.

A substantial number of the techniques which have been examined do, however, relate to Scottish house-building and wherever possible the examples have been drawn from the South East area of Scotland. From time to time it will be noted that Scottish building terms are used when describing the various constructional processes or parts of buildings, e.g. scaracement, deafening, rhouse, slapping, etc.; in most instances the meaning of the term will be obvious from the text, but where any doubt arises reference should be made to the Glossary of Scottish Building Terms included as an Appendix.

In a number of instances the critical examination/
examination of new methods has been supported by laboratory tests or trial, and for the facilities necessary to do this work I am indebted to the Principal and Governors of the Heriot-Watt College.

The difficulties encountered in the study of the economic aspects of the new methods proved to be far greater than were anticipated. Many contractors and others connected with the industry were approached for data on labour expenditure applied to particular processes, and in practically all instances there was a complete inability or unwillingness to provide the desired information. A similar result was experienced when attempts were made to obtain a representative selection of priced bills of quantities relating to house-building work that had included new building methods designed to save costs. My intention here was to analyse a substantial number of priced bills on an elemental basis, but it was possible to obtain only a relatively small amount of this type of cost data. The cost analyses based on these data are inserted in Appendix A to Part 2. Many letters of enquiry were sent to various contractors, manufacturing firms, architects, etc., and some extremely useful information was obtained in this way.
way. But it was quite the exception to receive a prompt and really informative reply to these enquiries. In many cases the enquiries were simply ignored - even by a number of local authority and private architects, who, one might have thought would have had the courtesy to reply, however unhelpfully.

These difficulties that have been described are in no way unusual: an extract from the 1956/57 Report of the Advisory Council on Building Research and Development reads - "It is difficult to establish the actual cost of the construction of separate structural components because few builders outside the largest firms operate exact systems of cost recording and there is an understandable reluctance to divulge detailed figures even when they are available; Government departments suffer from the same reluctance. In any case it is necessary to find out what kind of cost data would be most helpful to architects and how such data would best be compiled".

In spite of this regrettable dearth of detailed information it has been possible, with the co-operation of such organisations as the Scottish Special Housing Association and one or two research-minded contracting firms, together with/
with personal observation, much reading, and experiment to make a critical assessment of a selected group of techniques and in many cases, to publish factual information on productivity and cost.

Some extracts from this thesis have already been published in the Transactions of the Royal Institution of Chartered Surveyors and other technical journals, (copies of these publications are deposited with this thesis). It is hoped that a substantial part of the findings in the thesis will eventually be published in professional and technical journals and will serve, in a modest way, to inform the professions and the industry on these vital matters of productivity and cost.
Historical Development of Constructional Method.

One of the earliest constructional techniques to be employed in Scotland must surely have been the hollowing out of caves such as the "Dwarfie Stane" at the north of the Island of Hoy in the Orkney Islands. Here the builder, with the crudest of tools, formed a tiny space by enlarging a natural fissure in a small patch of outcrop rock in the middle of a barren waste of heather and marsh grass. A technique has been defined as a method or a skill, and it was indeed by the use of a new method that this early man carved out this space in the living rock. For ages past the old method had been simply to roll a stone in front of a naturally formed cave, but in this "Dwarfie Stane" the evidence of cutting marks in the walls of the cave supported the view that a crude tool had been used. Thus, a cutting method or technique had been employed, perhaps for the first time in those islands.

This evolutionary process continued and skill developed from use of the method. Better tools were fashioned and better caves were formed. Perhaps the first lean-to roofs developed from stones and earth sods bridging a gap between boulders and a nearby vertical rock face. There is evidence existing today of very early huts, built in irregular shaped stones and roughly circular in plan and following these the great circular stone-walled fortifications, called "the Brochs" were built.

Scotland's/
Scotland's earliest building forms followed the general trend of Gothic architecture from Norman onwards. The unsettled period from 1296 resulted in the building of large numbers of "Peel Towers" modelled on the style of the Norman keep, and these square shaped towered buildings, three or more storeys in height, determined the style of Scottish domestic architecture from the thirteenth to the seventeenth century. Building techniques developed steadily during this period, dry stone walling gave place to stone and lime mortar and other interesting developments included larger windows, increased use of stone vaulting, stone slabbled roofing, timber joists, stairs and properly formed chimneys and flues. All these methods had developed by the eighteenth century and then, with the coming of the Renaissance, the emphasis on building moved largely from isolated buildings in rural areas to the built-up pattern in urban areas.

Renaissance Domestic Architecture has many examples in Edinburgh where the new constructional techniques of that era were applied to the building of large numbers of terraced houses within the New Town. The methods of house building at that time - methods which today seem to have been so leisurely and so wasteful of materials and labour - must, to the Victorians, have represented great advances in constructional technique. One can almost imagine the learned arguments/
arguments and the shaking of heads over enlarged window openings with flimsy piers and panels sometimes as little as two feet in thickness!

The emergence of the middle class created a demand for new ways of living where the servant no longer lived separately from his master in mews or lodge but slept in an attic room built in the roof of the terrace house and worked in the basement. Thus the problem of keeping a basement dry and an attic skylight weather-resistant was solved only by employing new methods of construction. The need for the creation of dry areas adjoining basement walls must have exercised much ingenuity on the part of architect and builder in the design and construction of retaining walls and the drainage of low level floors. It is possible that the practice of "strapping" external walls developed about this time and in these circumstances of damp basement walling.

While steady progress in the development of new building methods continued in the urban areas, little or no progress was made in the rural communities scattered over the greater part of Scotland. In Dr. Johnson's account of his "Journey to the Western Islands of Scotland" during the latter part of the eighteenth century the following description of a Highland Hut appears:— " A hut is constructed with loose/
loose stones, ranged for the most part with some tendency to circularity. It must be placed where the wind cannot act upon it with violence, because it has no cement; and where the water will run easily away, because it has no floor but the naked ground. The wall, which is commonly six feet high, declines from the perpendicular a little inward. Such rafters as can be procured are then raised for a roof, and covered with heath, which makes a strong and warm thatch, kept from flying off by ropes of twisted heath, of which the ends, reaching from the centre of the thatch to the top of the wall, are held firm by the weight of a large stone. No light is admitted but at the entrance, and through a hole in the thatch, which gives vent to the smoke. This hole is not directly above the fire, lest the rains should extinguish it; and the smoke therefore naturally fills the place before it escapes. Such is the general structure of the houses in which one of the nations of this opulent and powerful island has hitherto been content to live ".

This description was written in 1773 and it is interesting to compare it with an account contained in a letter sent to me by a building student who recently visited the Western Islands :-

" This is a description of a type of house which is still fairly/
fairly common on the islands. The walls of stone, gathered from the hillsides and beaches are about six feet high, dry built in a manner similar to the dykes in the Borders and Lothians. Sometimes the walls are pointed with cement-mortar, but I have seen houses where the only protection from wind is by newspapers stuffed in the joints from the inside.

Foundations are rarely formed at the base of the walls and damp-proof courses are hardly ever seen. The roof is constructed of timber, sometimes the original branches three or four inches in diameter, forming a simple truss pattern with two rafters and a tie usually half-way up the rafters. The feet of the rafters are wired to the walls with fence wire to resist the force of the wind.

Over battens is laid the roof covering which varies according to the district, sometimes it is turf covered with heather, straw, hay or reeds. The finished roof is securely roped or covered with wide-meshed wire netting and weighted round the eaves with stones or a fascinating collection of scrap-iron. The roof is never stripped, the new covering being laid over the old. In many cases the thatch is a foul-smelling mass of rotten vegetation from which water drips continuously.

Usually, there is but the one door, set in the middle of one of the longer walls. The windows, three or four in number, generally measure about eighteen inches square and are/
Two Dwellings on the Isle of Skye.

At Ardvasar, the Isle of Rhum in background.

At Elgol, at the S.W. tip of the Strathaird

Peninsular.
Sketches of the Original Form of "Black House."

Elevation

Low Row of Stones as Byre Boundary

Plan

A Wooden Partition was a Later Addition

Lafilling of Peat or Rubble
are set flush with the inner face of the wall. Owing to the thickness of the walls there are very deep ingoes, causing quite a gloomy effect even on sunny days, so that lamps are often kept burning all day.

Of sanitation and sanitary fittings little or nothing can be said because they simply are not there. Water supplies are drawn by hand from the nearest well, loch or burn and carried indoors by pail.

The floor is usually of earth, beaten hard by years of use. In a few cases the floor is covered with a layer of rough-finished concrete. The area around the house is often a sea of mud due to the absence of rhones and downpipes coupled with the emptying of slops near to the door."

This comparison between 1773 and 1953 methods of house-building shows little progress over 150 years of building. It is of course, true to say that these remote islands have many special problems, there are few really skilled building craftsmen and there is no system of apprenticeship in the islands except, to a very limited extent, in Stornaway. And it was only quite recently, in 1954, that organised technical building instruction became available in Stornaway.

In the more thickly populated parts of Scotland the tempo of house-building quickened noticeably during the period/
period of the Industrial Revolution. Acres of squalid tenement dwellings sprawled outwards from the industrial centres until they coalesced into vast conurbations.

What development there was, during this period, of new methods of construction seemed to be directed to the elimination of sanitary convenience, the reduction of living space to a bare minimum and a drastic lowering of standards of craftsmanship in the interests of cost. It only needed the introduction of the "back-to-back" house to mark the line of the lowest ebb of this backwash of building low-cost houses for the industrial workers.

The first Public Health Acts and the provision therein for the making of building legislation had a decided effect on the planning, construction and equipment of dwelling houses. Although the planners deplore the dreary acres of "byelaw development" of that era, those early byelaws did stimulate the development of new techniques of construction. The new standards of sanitation demanded better plumbing methods and appliances. This was an entirely new field and the inventors of plumbing fitments surpassed themselves with hundreds of novel water closets, taps, valves, washbasins, baths and other sanitary fitments too numerous to mention. Many of these fitments turned out to be anything but sanitary over a period of use but the worst of them were surely/
surely better than the earth closets and ash tips in the older houses? This "byelaw development" continued up to the outbreak of the first World War and by then there had been decided advances in plumbing method and in the provision of more window area, ceiling height, etc. Very important also was the gradual recognition of the need for reducing fire hazard in buildings and the byelaws, in providing for this, laid down standards of construction and materials with special reference to fireplaces, hearths, flues and chimneys.

Meanwhile the Scottish tradition of building in stone which had persisted, almost unchallenged, until the latter half of the nineteenth century still held the field but the use of brickwork was gaining favour. Portland cement was slowly displacing lime in the making of concrete, but it was expensive at that time and had to be used sparingly. Welsh slates competed strongly with Scottish slates, providing an opportunity for lighter roof construction. The colourful red clay pantiles, so well known in Fife and the Lothians, were unable to withstand the competition of the cheaper slates and production was eventually discontinued. It is however, heartening to note that the Scottish Building Research Station is at the moment co-operating with the Fife clay tile industry in testing the physical properties of recently/
recently manufactured pantiles.

In 1919 the pent-up demand for houses following wartime restrictions was aggravated by a pre-war deficiency of houses. Prior to 1914 the annual total of houses built was about 58,000 and this total was considerably exceeded after 1919. But the demand for houses was not met and building costs rose rapidly until in 1920 final costs were estimated to be £1,100 per house. Legislation restricting rents had been put into effect but there was no control on the price of new houses or old houses.

By 1923 house-building costs had fallen and the trend of falling prices continued into the 'thirties. At the same time there was a considerable expansion of private enterprise house-building, stimulated by State subsidies. A fall in the cost of materials coincided with an increase in the labour force within the building industry; labour was cheap and plentiful and it was not surprising that little advance was made in improving methods of construction during these inter-war years. Such changes as there were can be quickly summarised: there was the slow change from solid load-bearing walls of stone or brick to steel or reinforced concrete framing, though the maximum benefit from this changeover was only very slowly realised owing to a general/

general reluctance of architects to depart from solid masonry walling in the non load-bearing panel walls. Steel window frames complete with fitted sashes began to compete with the standard wood frames but the increased manufacture of stock-sized wood frames by specialist firms reduced this competition to negligible proportions. This mass-production of joinery began with the production of internal doors by Scandinavian manufacturers and British firms were not slow to realise the potential market for cheap factory-made windows and stairs as well as doors. Another Scandinavian product which made its appearance during this inter-war period was the now familiar wallboard.

In Scotland between the wars, the pattern of housing development was different from that in England where the "modern semi" and the cheap terrace house were being built by the thousand. The Scottish demand was for bungalows, detached and with a stone front, together with two bay windows placed symmetrically about a central front entrance. Each bungalow was almost identical in plan to its neighbour and this gave scope for some standardisation in construction. The stone fronts were made up at the quarries in ranges of stock sizes, cutting lists of timber scantlings for floors and roofs were repetitive and the similarity of room sizes produced competitive pricing from the various firms sub-contracting the masonry, joinery, plastering, etc.
It was in the 1930's when cast stone and concrete components began to replace natural stonework and by 1937-38 a number of specialist firms manufacturing these components had become firmly established in the Scottish building industry. In the main the demand was for precast stone or concrete window heads, sills or dressings rather than for complete elevational treatment. "Harling" was still the most popular finish for external walling, particularly since brickwork had virtually replaced natural stone on all but the most expensive houses.

At the outbreak of the Second World War the great house-building machine was simply allowed to run down to a standstill. Most of the labour force was transferred to civil defence works and, after a time, only the older operatives escaped call-up to the Forces. Some useful constructional experience was undoubtedly gained from the colossal programme of civil defence works though there was little time for planned research during the early days of the War. It was a process of trial and error and there must have been a great wastage of steel and concrete at that time.

Very soon however, in 1941, the Government made a start with the planning of the post-war housing programme and Committees were set up to consider and report on the many aspects of building. These included the Dudley Committee on the Design of Dwellings, the Burt Committee on House Construction and Committees on Codes of Practice in Building, Contracts, Private/
Private Enterprise Housing, Standards in Building, etc.
The recommendations of these Committees were extremely helpful and in many cases prescribed standards which were an advance on pre-war practice.

Whilst these Committees were deliberating, the Ministry of Works prepared plans for prefabricated houses and production was started early in 1945. Demonstration houses were erected earlier than this, following up the research and experimental work which had been done on new or non-traditional methods of building. Prototypes of houses of all types were constructed; they included temporary and permanent dwellings in materials ranging from aluminium to precast concrete.⁶)

At the same time, local authorities were asked to prepare housing programmes, to purchase building sites and to put the preparatory site work in hand. Thus, by the Spring of *1945 nearly 300,000 permanent houses had been allocated to sites all over Great Britain and a large number of temporary houses had already been built.

But most post-war planning had been based on the assumption that there would be an acute shortage of skilled labour and building material, chiefly softwood and bricks. Consequently much attention was directed to the planning of houses with a load-bearing frame of steel elements and a cladding which could be put in place by semi-skilled or unskilled labour. It turned out however, that the output of bricks was higher than had been expected and skilled operatives were released from the Forces/⁷)

Forces in greater numbers than had been forecast, with the result that traditional types of house-building competed freely with the new methods. At that time the engineering industry had turned to a vast programme of re-tooling, re-equipment and re-organisation in preparation for a tremendous export drive, and, with the uncertainty of demand for factory-fabricated houses caused by this unexpected renewal of traditional building, it seems true to say that the production of prefabricated houses for the home market failed to achieve its optimum.

As a consequence of all this, Government policy was concentrated on the provision of permanent houses by local authorities and the programme providing for temporary (factory fabricated) houses was not extended after the fulfilment of outstanding orders. The factories still played a part, of course, in making component parts of the non-traditional permanent houses.

In describing post-war housing construction some mention should be made of the house-builder. The great landowners, whose influence had been so considerable in initiating private house-building after the 1914-18 War were fast losing ground in this respect and the Town and Country Planning Act of 1946 must have given the "coup de grâce" to this dying form of house-building agency.

This vacuum caused by the withdrawal of the familiar private enterprise builder together with the large landowner was filled by the large housing authorities, the Scottish Special Housing Association and the New Towns Corporations. And this set the/
the stage for the tremendous drive towards the erection of houses in ever increasing numbers from 1946 to 1954. Over this period the annual output of permanent houses built by local authorities, private enterprise and other agencies in

* Scotland grew from 4,310 to over 30,000. In order to achieve these figures the producers of building materials built up their production to the extent that in Great Britain the total annual output of bricks was 7,000 million in 1954 and in the same year the cement manufacturers produced nearly 12 million tons of cement.

In spite of these figures for material production there were serious shortages of building materials, particularly in Scotland where bricks and cement came largely from England. It must be remembered that the National Coal Board had not developed its great programme of brick production until some years after 1946 and any cement shortage in England was and is felt first by Scotland in the same way as any other importing foreign country. It is argued that in the interests of economic distribution, in times of scarcity, cement can be shipped from Belgium or Germany or Sweden, but much of this foreign cement is subject to two disadvantages - it is always expensive and there are apt to be marked variations in strength and other properties.

As a consequence of these shortages of materials and of skilled labour much invention and ingenuity found expression/


expression in new forms of construction and in mechanisation. When the shortage of timber in 1946 made it necessary to restrict the amount of softwood to 1.6 standards per 1000 sq. ft. of floor area, solid ground floors were substituted for the conventional timber joist and boarded floor, safe limits for dimensions of timber in first floor and roof construction were carefully worked out to a bare minimum and new forms of laminated timber roof trusses were designed. It must be stated here that Scotland was generally slower than England to adopt the restricted timber sizes, even at the most critical period of the timber shortage. Scottish houses have always been constructed of heavier roof and floor timbers than appear in English houses, presumably because the early roof coverings of thick Scottish slates needed additional support. The trouble is that Scottish architects and builders persist in specifying and using timbers which are more than adequate for the loads they have to support.

In the main, the new methods of house-building from 1946 onwards aimed at reducing the amount of skilled labour on the site and this was achieved by the increased use of machines and by a wide range of novel forms of external wall construction. The new forms of walling included solid walls of "no fines" concrete, precast concrete frames with precast concrete/
concrete internal and external slabs, large crane-handled storey-height walling slabs of precast reinforced concrete, steel framed walls with various forms of cladding, and many others.

This historical review of the development of new constructional methods has shown how the early Scottish forms of construction persisted over the centuries, sometimes to most recent times. 'Evolution, not revolution' might well be the slogan of the builder, steeped in tradition and resistant to change. He must necessarily move with caution, for after all, the builder cannot, when new methods or materials fail, order his creations to be "grounded" like an aircraft which has advanced disastrously ahead of safe design limits. But allowing for this need for caution, the record of progress in the building industry is very poor indeed, at any rate as far as 1946 when admittedly the tempo quickened.

The housing situation today will be helped by the undoubted existence of progressive-minded architects who are employing themselves in the respective spheres of private and state-aided housing. There are also many of the larger firms interested and well able to employ new methods but there still remains a vast number of small building firms equipped only for traditional building in the style of the last generation.
**Scottish Contracting Methods.**

The proportion of single trades contractors in the Scottish building industry is far higher than in the English industry in which the number of trades contractors has, over the last hundred years, shown a steady reduction proportionately against the "all trades" contractors. In England one finds that most building contractors, however small, have three or more of the trades represented in their organisations. First there is the carpenter and joiner team, then the bricklayers and then possibly a minimum of one plumber and apprentice. In addition there may be a painter section and plasterers, etc. according to the size of the firm.

In Scotland, only the very large organisations have an "all trade" representation and the number of such firms is very small in comparison with the thousands of small single trades firms. There appears to be no obvious explanation of this quite striking difference in contracting organisation as between the two countries and an attempt is made here to state the case for and against the Scottish system and to assess future developments in contracting method.

This large proportion of small trades firms in Scotland obviously has a pronounced effect on contracting method. The practice of sub-contracting the separate trades is commonly adopted throughout the industry.
Apart from the practice of sub-contracting the separate trades within a main contract it is quite usual in Scotland for a local authority's Architect or a private architect to invite tenders for work on the basis of "separate trades". Indeed, in many instances the local authority is insistent that the single trades firms shall have an opportunity to submit their individual tenders, for it has been the general experience in S.E. Scotland for the aggregate total of these single tenders to compare favourably against tenders for grouped trades, often to the extent of 5% lower.

Quite often the private architect will have a favourite group of single trades firms and he will send each one of them an invitation to tender, together with a schedule of quantities which has been specially drawn up by the quantity surveyor so that it covers the section of the work relevant to the particular trade firm.

It is seen then, that the Scottish separate trades organisation can operate in two ways:—(1) as a sub-contractor under a main contractor, or (2) as a contractor in his own right, working side by side with other trades contractors. In developing the arguments for and against the Scottish system, I have generally regarded the two forms of organisation as sub-contractors. Some consideration is however given to the differences between these alternative methods of contracting.
Those who favour sub-contracting by trades claim the achievement of greater efficiency through a marked reduction in man hours, and indeed it was confidently stated in a Building Research Station Survey of 177 completed contracts in England and Wales between 1949 and 1951, that on average, the labour expenditure of sub-contractors employed in house-building during the period covered by the survey was at least 15% to 20% less than the average labour expenditure of main contractors for the same work. (*10)

This saving in man hours is mainly due to the sub-contractor's ability to operate as a small, well trained team of craftsmen and labourers, led by the principal of the firm who is often the leading craftsman. All site work is reduced to a simple repetitive drill, the proportion of labourers to the craftsmen is just right and they know exactly what they have to do. The men are all hand picked by the principal, he understands their capabilities, their whims and idiosyncrasies, while from the workmen's point of view they respect their employer as a workmate and a craftsman and little time is lost in airing grievances or in industrial disorders so common to the larger firms where personal contact between master and man is lacking.

The separate trades contractor can afford to equip himself/*

himself with special mechanical plant or machinery, to meet the requirements of his particular craft; for example a joiner firm will install woodcutting machinery of various kinds and, what is most important, will keep that machinery working more continuously than a small comprehensive contractor is likely to do. The brickwork and masonry firms will have hoists and other labour saving equipment for moving heavy materials, the plumbing contractor will have pipe-cutting and threading equipment and perhaps welding or lead burning apparatus as well; the plasterer firm too will carry a certain amount of special equipment, including maybe, powered mixers.

The scale of operations on which the trades sub-contractor works is so small in comparison with the main contractor, the risks in tendering for work are proportionately lower and keener prices can be quoted. It often happens that out of a group of sub-contractors tendering for the same contract, there is one firm which is desperate for work and will cut its price to the minimum in order to obtain the contract. This happens in the case of "all trades" firms but not nearly to the same extent, for it will be appreciated that if a contractor's bricklayers happen to be idle his joiners and plumbers are not bound to be short of work also, hence the contractor cannot reduce his tender price merely to find work for perhaps a third of his employees, though he can of course reduce his rates for that particular trade within the Schedule.
The sub-contractor often works in combination with another trades sub-contractor on what might be called small jobbing work. A common instance of this is where a brickwork firm goes in for fireplace fixing and carries a stock of new fireplace surrounds, ranges and the like; old fireplace surrounds and ranges are removed and this quite often requires the services of a plumber, who is concerned also with the installation of new hot-water systems. On this type of work and on maintenance and repair work also the brickwork sub-contractor will favour a certain plumber and will put what work he can in the plumber's hands. In turn the plumber will call in the brickwork man to combine with him on his jobs and the same sort of thing happens with the joiner firms and the plastering firms.

Quite often, two or three firms representing different trades will cooperate to such an extent that they will loan plant, materials and even unskilled workmen to each other as the need arises. For example, the brickwork sub-contractor quite frequently carries up the joiner's roofing timbers on a housing job, uses the rafters, etc. for scaffolding, and then leaves them in readiness for the joiner when he puts on the roof. This tendency to work in combination with old associates certainly acts in the interests of efficiency on repairs and small new works but on the larger buildings put out to open tender these local combinations rarely find themselves keeping company together.
What are the criticisms of building by separate trades contractors? To begin with there is the obvious difficulty of co-ordination and supervision. All the various trades must follow on without wasteful overlapping or delay; the main contractor often does his own excavating and concreting work and the first sub-contractor he must contact is the bricklayer who is followed by the joiner, the slater and then the finishing trades. Is it likely that each sub-contractor will time his appearance just to suit the main contractor? Usually the sub-contractor tries to ensure a full run of work by tendering for just that little more than he can handle at one time; then when he has the work to do he arranges his own progress schedule to suit himself. Unfortunately this independent planning function of the sub-contractor is apt to clash with the overall programming requirements of the entire project, with the result that delays occur which upset the whole sequence of operations, setting up a chain of reactions which make for further delays and consequent loss of production. A brickwork or joinery group working within a comprehensive firm can be ordered to start work on a particular job on a set date, but a sub-contractor must be asked; quite obviously this absence of positive control over such important and basic operations is prejudicial to coherent planning and must inevitably increase costs.
In any criticism of the Scottish system of separate trades contractors the main arguments must assuredly fasten on the separation of interests, the inevitable duplication of processes and functions and, as has already been discussed, the difficulty of attainment of close integration in a planned programme of work.

In developing the argument based on the separation of interests, reference is first made to the absence of cooperation between the various trades. What, for instance, happens when holes or chases have to be cut in brickwork or masonry for the finishing trades, and the brickwork subcontractor is away on another site? The answer could be that the plumber must cut out such holes as he may require, but while this be all very well in covered brickwork it is folly to allow a plumber to cut holes in facing work, and in either case the holes have to be made good by a sub-contractor who is likely to wait until all the making-good in the entire building or block of houses is ready for him.

It is the separation of interests that leads to duplication, and of all the instances of duplication the uneconomic repetition of scaffolding for nearly all trades is probably the most outstanding example. On general housing/
housing in Scotland the scaffolding provision could hardly ever be described as adequate by English standards. In England, the "all trades" contractor predominates and it is usual for him to carry a considerable stock of scaffolding sufficient for his day to day needs. When a building of two storeys or more is commenced, a proper external system of scaffolding is set out by a competent workman, usually a labourer who has been trained in the work, and the first "lift" is ready for the bricklayers when the walling has risen some five feet or so. The scaffolding is generally a minimum of five planks in width and is carried up as the work progresses to eaves level with supplementary scaffolding for chimneys and gables. All the scaffolding remains in place until all trades have discharged their several functions.

In Scotland the usual arrangement is for each of the sub-contracting trades to fend for itself, and this results in makeshift provisions that would never be tolerated in England and certainly will not be tolerated much longer by H.M. inspectors of Factories in the exercise of their duties under the Safety and Welfare Regulations. The brickwork sub-contractor builds up from ground level and by the use of trestles and planks or drainpipe or brick packings as supports to putlogs and planks, he completes the walling up/
up to the level of the first floor joists. Then the joiner places the joists in position, working initially from a ladder, or, if permission is given, from the brickwork sub-contractor's trestle scaffold. Then the bricklayers spread their few planks over the floor joists and proceed to build the external walls "overhand" until the trestles are brought into commission again to permit this "overhand" building of the walls up to wallhead level.

It is at this level that matters become a little precarious and access to the higher parts of the structure is gained principally by a ladder. The bricklayer again pulls up his trestles and planks, supplemented sometimes by the joiner's roof timbers, and finally the chimneys are topped out and the joiner is left to complete the roof structure. By this time the bricklayer's crude scaffolding will most likely have been removed to another site and the joiner makes shift by working from a ladder and inching his way along the wallhead until his work is done and he can hand over to the plumber and the slater.

The methods employed by the independent plumbing sub-contractor, the slater and finally the person responsible for the "harling" of the walls, vary from combinations of long/

* Scottish term for roughcasting.
long and short ladders, brackets and planks to tubular steel scaffolding. The improvisation and ingenuity displayed in many of these forms of external scaffolding are expressive of the temporary nature of the scaffold which has only to serve the particular tradesman responsible for it. In many cases the working width is reduced to two planks or less and the guard-rails and toe-boards prescribed in Regulation 24 of the Building (Safety, Health and Welfare) Regulations are generally disregarded.

Each separate trades sub-contractor is intent only on his own job. If he has a trench to fill in, a board to nail in position, or a hole to brick up, he completes the work even though he may know quite well that the trench may have to be excavated again for a following trade or for the same reason the board will have to be prised off and the hole re-opened. There is scant respect paid to other tradespeople's work when it stands in the way of the individual craftsman who has to complete his task and move on. If he is un-cooperative in his relationship with another craftsman who shall reprimand him? certainly not his own employer if he is getting on with his own job.

The duplication of materials deposited on the site, the wastage of labour and transport caused by half empty lorries carrying odd bags of cement and half-loads of sand, these matters/
matters all add up to a great waste of effort and expense which could be avoided in a well organised "all trades" firm functioning under the influence of proper central coordination.

In Scotland, the Clerk of Works often finds himself burdened with the task of coordinating the several trades groups together. Clearly this should not happen, for it is no part of a Clerk of Works' duty to act as a general foreman or site agent. This does happen however, for although there may be a foreman on the site, representing the main trades contractor (usually the joiner firm), the inherent weakness in this arrangement lies in the fact that this foreman is a craft foreman, not a general foreman. Usually, he will have obtained his training and experience in a single trades firm; hence he is probably ignorant of the basic principles of job management and their application to systematic organisation and administration.

This criticism leads to another; one that concerns perhaps the future of the single trades firms - the failure of the Scottish contractors to foster and encourage advanced studies in general foremanship and management. It is the very structure of the Scottish building industry, being as it is, a complex tangle of small trades firms, interspersed/
interspersed with one or two large organisations, that is mainly responsible for this apathetic attitude to the need for training future administrators for the industry. The small single trades contractors have little use for administrative executives, consequently they display no interest whatsoever in the training of them. This is quite understandable; and even if the smaller firms were to encourage the education of higher supervisory grades, they would only be making the way easier for the more extensive development of the few larger organisations which recognise the need for properly trained supervisors.

This impasse must be overcome somehow, otherwise the field of opportunity must remain open to the large English firms which have had the benefit of well organised courses in Building Foremanship since 1948 and are competing successfully with Scottish contractors for work on this side of the Border. Fortunately there are a few, only a very small number, of large contracting firms which, originally part of large English organisations, have developed Scottish interests and settled permanently in Scotland. These are the enlightened contractors, from which the technical institutions draw support for their special courses ranging from Concrete Technology to Building Foremanship, and from whom they get a ready/
ready response when full-time Building students are needing vocational work as trainee site agents.

Continuing this critical examination of the merits and shortcomings of the single trade firms, some mention should be made of which must be a considerable duplication of clerical staff and routine office administration. Admittedly the firm employing only three or four operatives together with a working principal will hardly be likely to carry full-time clerks on its books, but for any firm, no matter how small, there is a telephone to be answered, accounts to be reckoned up and sent out, estimates to be typed, and a host of other office tasks which require knowledgeable attention.

These administrative chores, where they are carried out, must engage an army of spare-time accountants, book-keepers, income-tax specialists and the like. More often than not, the trades contractor struggles along with a great accumulation of arrears of filing, accounting, etc., so that he rarely knows from one half-year to another whether he is solvent or not! This is no exaggeration, indeed were it not for the stimulus of the bank manager on the one side and the income tax inspector on the other, the hard worked sub-contractor would scarcely ever pause to assess his costs, his income and his profits.

The/
The small trades contractor may recognise the necessity for an organised system of costing and he may be able to maintain a record of his costs on traditional or conventional types of work on a small scale; but with such a small organisation he is rarely able to keep in touch with new forms of construction and his tenders for work which does not conform to traditional standards are inclined to be very approximate and unrealistic.

The large comprehensive firm has its costing department, its quantity surveyors, building surveyors, engineer site agents, building site agents, general foremen, craft foremen and chargehands. There is also, in the more progressive organisations, a small department devoted to research, testing and new development, and in one large Scottish firm the administration on the staff side is developed to such an extent that every member of the staff is the subject of three entirely independent and separate confidential reports. These reports constitute a basis for promotion and every effort is made to ensure a fair and unbiased report in every case.

From what has been said, it must be clear that the smaller units in the building industry must necessarily be incapable of defining a management policy and of detailing a procedure which is likely to give effect to such a policy.
The organisation of the building industry in Germany is very similar in structure to Scotland. There are very many small trades firms and it is customary for German architects to deal directly with these firms and to coordinate them on all types of contract, large and small. The architect employs a specialist who is known as the supervisor and this specialist is delegated the task of the day to day supervision of the site work. This lines up rather with my previous note on the Scottish clerk of works being saddled with the organisation of the trade firms, but the German supervisor appears to have more responsibility in that his duties include the making of recommendations for changes in technique, modifications in design, etc. as the building work progresses.

When Mr J. Gloag visited Germany in November 1954 to study the progress of rebuilding there, he made extensive enquiries among the German architects to discover whether opinion was in favour or otherwise of the single trades system of contractors. In general he found that seven out of ten architects were strongly opposed to the system; they considered that the architect should not have to deal separately with innumerable small firms, (on the Silcher School at Stuttgart, a hundred and ten different firms were employed) he should be free to give more time to creative work,
work, rather than occupy half his waking life on the telephone unravelling the complex tangle of administrative detail.

The minority of architects who declared themselves in favour of the German system did so because they felt that the architect was completely free under the system to change his mind, to make new decisions about the planning of the building or to make experiments. In order to understand this reference to freedom of the architect, it is necessary to explain that it is not the practice of German architects to provide detailed drawings for their jobs, neither is the pinned down so firmly as his British counterpart to a fixed design.

According to Mr Glaag's description of his cross-questioning of the advocates of the German system of direct control over the various building trades the following point was made: "How can an architect avoid becoming lazy and content to accept existing techniques and materials, if he isn't constantly given an opportunity to improve his building as he puts it up, and, compelled by his method of working, to study afresh every trade on every job".

Not every British architect would agree with this, though he might be in favour of the Scottish single trades system; indeed only a minority of German architects supported this strange idea of "plan as you go".
The incidence of full employment has tended to obscure the relative advantages and disadvantages of the single trades firm. What are the conditions likely to be, for instance, in such a firm during a sharp recession of trade? Clearly, the smaller firm will not have the reserves of the larger comprehensive organisation and owing to its faster turnover of work the trades firm will be first to meet the challenge of idle hands and their disposal. The "all trades" firm can often offset its losses on one section against another during slack times. And, of course there can be a certain amount of interchange of unskilled labour between the various sections. On the other hand, during the present period of full employment a single trades firm will nearly always be working at full speed while the comprehensive firm has, perhaps, four out of five sections fully employed but the fifth section may be waiting on one of the other four.

Attempts have been made to draw an analogy from the motor industry where specialist firms fabricate car bodies, wheels, tyres, etc., and the main manufacturer puts the components together. But there is such a world of difference between the two industries, one only partially prefabricated and the other wholly prefabricated, and comparisons in such circumstances are of little use.
At this stage in this investigation of contracting method in Scotland an effort was made to obtain a representative opinion on all the points outlined so far. Opinions were obtained from a group made up of four architects, three quantity surveyors, three single trades contractors, two all trades contractors, two municipal surveyors and a representative of H.M. Inspectorate of Factories.

From the opinions which were expressed it seemed obvious that the Scottish members of the group had had little experience of all trades contractors. Two of the architects had practised in England and preferred the all trades firms but admitted that house-building costs in Scotland seemed to be lower than those experienced in England where the all trades firms are fairly general. One of the Scottish architects was in favour of the all trades firm with, however, certain reservations, mostly to do with cost. I was allowed to inspect various jobs which these architects had in hand, some with single trade contractors and others with all trades or main contractor and sub-contractors on the site.

The main body of opinion appeared to be in favour of the present Scottish system of either a group of single trades contractors or main contractor heading a team of subcontractors. This opinion rested mainly on the grounds of/
of cost. Several rather interesting viewpoints were put forward, for instance it was held that the architect, as titular head of any building team, is well qualified to coordinate the work of the separate trades, also that cooperation between the several trades is generally good because the architect (or main contractor) usually picks the same group of single trades contractors which have worked well together before. It was argued that an architect and his client have greater selectivity in this connection - they can, for example, choose a particular joiner firm with a reputation for good work without having to accept other trades in which the standard of craftsmanship is not so high. This is, of course, perfectly true where one requires, say, high class joinery for a bank or similar commercial premises, but the point is not quite so applicable to house-building.

It is surely quite illogical to place the onus of coordination upon the architect, for in a fixed price contract it is the contractor and indeed the sub-contractors too who benefit from efficient job management; it follows then that the main contractor should bear the responsibility for the coordination of his undertaking, but the answer is not so simple where the work is done by a number of single trade firms, all on an equal footing. Here the architect is bound to undertake the organisng of the work, for there is no one/
one else. Perhaps there is an opening here for a professional building consultant, nominated by the architect; the consultant's fees would be paid by the single trades contractors pro rata, according to their share in the entire contract. The building consultant would have to be something of a quantity surveyor, builder and administrator combined; he would need to be highly skilled in job organisation and personnel management. His interests would be those of the employing contractors and would consequently be linked with the necessity for making a profit for his employers; perhaps his fees might consist of a basic fee plus a percentage of profit made.

The creation of yet another professional member of the building team might be open to considerable criticism, certainly the architect should welcome the idea for it would relieve him of the many administrative duties which he is now called upon to do. The contractor too should surely be able to appreciate the advantages of having the services of a trained coordinator on the site, ensuring that the work goes smoothly and efficiently, and - profitably!

It is difficult to see any other way of ensuring the efficient running of these teams of single trades contractors unless the Scottish architects continue to do so and this suggestion/
suggestion might well deserve the serious consideration of Scottish architects in general. There are two essential requirements:-(1) the insistence by the architect on behalf of his client on the employment of approved overall supervision by the various single trades contractors, and (2) the availability of competent consultants, acceptable to architects and contractors, who would undertake the work.

The first requirement could easily be met but the second might be a little difficult in the early stages. The Royal Institution of Chartered Surveyors would probably not take kindly to a chartered quantity surveyor engaging in work of this kind unless he retained full and independent professional status. A good clerk of works with a flair for job management would be acceptable—indeed he already has to combine his normal duties with those of a site agent on many sites in Scotland where no site agent or general foreman is available. An ideal type of man for the work would, perhaps, be one with a full-time Diploma in Building or a university graduate in Building Technology, coupled with a minimum of ten year's experience in a large comprehensive contractor's organisation.

Leaving this question of coordination for the moment and returning to the other points which the various architects, quantity surveyors and contractors have raised, my attention was/
was drawn to instances where large "all trades" firms had secured contracts on very low tenders based on a negligible margin of profit and these firms, it was alleged, provided for their normal profit by putting in a high rate for additional underbuilding, knowing full well that a substantial amount of underbuilding was likely on the particular sites. On one housing scheme recently completed near Edinburgh the contract price per house was £1600 but the final cost was £2000 for each house, due mainly to this costly underbuilding.

The argument here was that a single trades firm would have done the excavating and underbuilding at keen rates and would not, as was suggested the large firm does, be constantly seeking an opportunity to swell narrow profit margins by measured extras.

Considerable mention was made of the large overhead expenses of the comprehensive firms due to an expensive section of non-productive personnel. In support of the smaller firms it was pointed out that financing was much easier for them. Their risks could be assessed so much more simply than those of the larger contractor and as a consequence of this their profit margins were more realistically based and keenly competitive.

The chief surveyor of a large Scottish firm which is about/
about two-thirds comprehensive spoke of the difficulty of keeping a plumbing section together owing to the relatively fluctuating demand for plumbing services. This particular firm combines a large staff of bricklayers, joiners and concreters but almost invariably sub-contracts the plumbing work in all contracts undertaken and covers the sub-contractor's price by a 2½% to 5% profit margin.

A further criticism of the large "all trades" firms was that the various trades were often separated in watertight departments to such an extent that they might well be separate trade firms. The system in one large firm in the Edinburgh area certainly supports this argument, for main tenders are made up from individual prices given by the head of each trade section within the firm. Sometimes these "sub-tenders" are compared with prices obtained from outside single trades firms in order to test the competitive quality of the sections' prices.

* One English architect who has designed a Scottish housing estate of some 1800 houses for a large local authority had many interesting experiences in using the various types of contracting method. The first 200 houses were put out to tender, and as is generally the case the lowest price was the aggregate of the lowest single trades contractors'/

* Mr. Stratton Davies, A.R.I.B.A. - The Inch Estate, Edinburgh.
contractors, consequently these first 200 houses were built by the team of trades contractors under the supervision of a clerk of works acting for the local authority. The prices were quite keen and the contractors were asked to take on the remaining 1600 houses at the same rates; this they would not do because they had not the labour and equipment necessary to handle such a large number of houses at one time, neither had they the financial resources and organisation to cope with the demands of such a large project.

The method finally adopted for the remainder of the houses was rather novel. A number of contractors, large and medium sized, were invited to contract to build certain blocks or parcels of these houses at fixed prices based on the prices already obtained from the small single trades contractors on the first 200 houses. Each contractor was to choose the particular block of houses which suited his organisation best. There were blocks of fifty and larger blocks of two hundred or more; each contractor was expected to be responsible for all the work on the particular parcel of houses chosen, and they were given specific targets of so many completed houses per week.

In a number of cases the price rates had to be stepped up a little in order to persuade the contractor to come/
come in. Naturally certain of the sites differed from one another and some presented difficulty owing to awkward contours or undrained areas.

With such a wide selection of contractors working on the entire site—the original single trade contractors, a few large all trades contractors and many sub-letting main contractors—the architect had a unique opportunity for observing the merits or otherwise of the different forms of contracting organisation. According to him, the comprehensive firms made the best showing on speed of completion and caused him the least work in co-ordination and supervision. Certain of the sub-letting main contractors did very well but there were many delays that were due to inefficient all-round supervision by inexperienced foremen.

There was general agreement with the points that I had made about the Scottish tendency to do without a proper external scaffolding and one architect wrote saying that he was convinced that workmanship invariably suffers at verges and such extremities as a result of inadequate scaffolding. On my notes on the small single trades firms’ methods of keeping accounts this same architect thought that in his experience this presented a really serious aspect of the problem, for he had traced countless hold-ups to the inability of/
of the small contractor to meet accounts for his materials at the proper time even when he may be getting substantial monthly certificates. He found that this was particularly noticeable among slaters.

The following extract is from a letter written by a Scottish architect who is rather critical of the large comprehensive organisation and prefers the main contractor with all trades other than his own sublet :-

"I feel that your reasoning that the comprehensive contractor has it on all sides since he has a complete group of trades within his own organisation which can be planned to the most economic use is questionable. If you think of this type of contractor with a long and steady series of acceptances for housing schemes, you can take it, I think, that his demand for bricklayers will be fairly constant. For every hundred houses he builds he will require approximately the same number of bricklayers for the same length of time, but in some of the other trades the demand is not nearly so consistent. Take on one hand, a large development of housing with solid floors on the ground floor and, say, flat bitumetal roofs; the demand for carpenter work is very slight indeed. If you imagine a scheme with precast concrete first floor slabs, then the need for the carpenter almost disappears. The next scheme however, might be for houses with timber upper/
upper floors and pitched timber roofs - while the first scheme is going on the big contractor's carpenters are going to be at a loose end and he has one of two alternatives, either he carries a large squad in which case his tendering will generally be higher, or he pays them off, in which case his second scheme will suffer since it will take him time to weed out the bad workers etc. Now I agree that the same can happen to a specialist carpenter and joiner contractor but it will be, I think, to a much smaller extent. It seems to me that unless the comprehensive contractor is so enormously large as to represent the equivalent of all the small contractors in, let us say, South East Scotland, he must encounter an enormous number of quiet periods for various trades which, in the end will add to his overheads tremendously. In addition it seems to me that part of your reasoning is based on the assumption that your large comprehensive contractor is working exclusively on housing, but in fact a firm of this size would be engaged on all types of building work so that the diversity could well become even greater, given say a contract for a hydro-electric dam requiring virtually only two trades. It seems to me that in Scotland, in the immediate future at least, the choice must lie between single trades contractors and main contractors who sublet all trades other than their own."
Summary

Briefly summarising what has been said about Scottish contracting methods, the figures given in the Building Research Station Survey 1949/51 are impressively in favour of the sub-contractor for house-building and this seems to put the Scottish system, with its great number of single trade contractors, ahead of the English system.

The more intimate relationship between employer and operatives in a small unit makes for a greater and more sustained volume of work. The small "single trades" firm has developed its trade function to such an extent that it could be described as a specialist firm that has achieved a level of "know how" rather higher than that obtaining in the large comprehensive firms.

On the question of cost the evidence appears to weigh in favour of the existing Scottish system varying between the single trades and main contractor types of contract but there is general agreement that contracts made with the large all trades firms are more satisfactory from the point of view of supervision and prompt completion. Unfortunately the additional expense of supervision and coordination by Scottish architects and the uneconomic consequences of vast capital resources tied up in slow moving/
moving development are factors rarely considered by the committees which have to deal with the selection of the successful tenders.

**Future Developments.**

In any consideration of future developments it must be remembered that the present system of small firms in Scotland is one which has developed from the time when the mason built the complete shell of the building long before the joiner came to the site. The joiner could insert the joisting and erect the roof in a completely separate operation and the other trades could follow on in the same detached manner with little or no contact with one another. This was very different to the traditional English method with brick walls, built-in joists and window frames, etc., and it is quite likely that these differences have been reflected in the development of the respective patterns of contracting method in England and Scotland.

The Scottish system of building in isolation has endured for a long time and any change can only come about slowly. These small firms exist in their thousands and they will continue to exist for many years despite criticism, valid or otherwise, of their place in an economic industrial structure./
structure.

The future pattern of the entire building industry is likely, in my opinion, to be influenced by a gradual lowering of craft standards. The steady increase of demand for prefabricated components, the trend towards the elimination of wet processes and the irresistible demands of the people in this new atomic age must inevitably bring about revolutionary changes in building methods. House-building is likely to be reduced to a simple routine of fixing by operatives trained only in such work.

The larger all trades firms will be better fitted to adjust their organisations to such changes by means of a gradual shift of emphasis from traditional craft methods to the "new" methods. They can build up a larger number of the semi-skilled fixers, recruited from the labourer grades, and at the same time/proportion of skilled craftsmen would be allowed to diminish until the right balance was obtained, according to the type of work undertaken.

In these circumstances the small single trades firms may well encounter difficulty in finding sufficient employment on traditional walling, roofing, plastering, plumbing and painting, and though it may seem sheer heresy even to contemplate craft dilution on such a scale, there are signs,
signs already that house-building, at an rate, is being reduced to a process of routine tasks which are hardly suited to the capabilities of fully trained craftsmen. For example, roof tiling in England is now almost the universal covering for the smaller housing units, and most of the tiles are of concrete and are manufactured and fixed by a few very large firms. These firms are refusing to send their young fixers to craft courses in the technical colleges because they claim that they can teach their own people all they need to know about fixing concrete tiles in a very short time. The trowel trades, plastering in particular, are finding less employment in modern low-cost housing than ever before, and such work as there is for them is of a very simple kind such as skimming over plasterboard or building straight lengths of brick walling.

So we may see a future building industry in Scotland, containing an increased number of large comprehensive firms staffed by teams of specialist "fixers" and a relatively smaller number of traditional craftsmen; the single trades firms must inevitably decline in numbers and the survivors will most likely be those specialising in high class work as applied to commercial or public buildings. These small firms, in their present numbers, are, I consider, bound/
bound to come up against increasing competition from large well organised all trades firms. The present level of building activity is not likely to be maintained continuously over a long term and any cessation of this activity will impose a severe test on the industry as a whole. The small firms are already organised within their own limitations as well as they possibly can be, while the possibilities for improvement of productive efficiency in the larger firms are considerable, particularly when building employers begin to understand and apply the principles of good management and architects can persuade their clients to believe in the benefits of pre-planning.
The Education and Training of the Builder.

The training of the craftsman in building was first undertaken by the Church as far back as the thirteenth century when the friars moved among the people and passed on to the craftsmen the knowledge and skills they had acquired in Europe. Many craftsmen were in the employ of the Church, certainly the best were, and these secular craftsmen often spent the whole of their lives, from apprenticeship to leading craftsmen, on buildings like York Minster or Canterbury Cathedral.

It was during the fourteenth century when these building craftsmen began to organise themselves in craft Guilds so that their rights and privileges could be better protected and also that the secrets of their crafts could be passed on to Guild members and the standard of craftsmanship maintained and improved. Professor Lethaby in his book on Medieval Art wrote that mastership of a Masons' Guild was only gained by serving a seven-years apprenticeship to become a bachelor or companion, then afterwards presenting an approved work-thesis. This mastership was considered to be closely parallel to master of arts in a university.

The old Guilds thus had a strong influence on the training and education of the early craftsmen. Unfortunately this influence waned as the centuries passed and the industry grew.
grew up. The number of journeymen increased considerably and the masters developed into what might be called commercial master builders working for their own personal interests rather than those of the Guild. A few of these old craft Guilds still exist, the Worshipful Company of Carpenters with the British Institute of Certified Carpenters have the strongest organisation, and apart from a craft school of their own in London they offer many prizes and other inducements to young carpenters in the interests of finer craftsmanship. The Guild of Bricklayers has members all over the country and its chief aim is to improve the standard of craftsmanship in brickwork.

Until the 1920's the building apprentice received his tuition from the journeymen around him, the craft foreman and sometimes the master-builder himself, (according to the dictates of his conscience and the extent of his ability.) With the added complexities of tendering, insurances, taxation and administration generally, the master-builder had lost personal contact with his apprentice, but there were still opportunities for him to follow the progress of these boys and to see that they were placed on a comprehensive range of building types throughout the period of their apprenticeship./
apprenticeship.

The last war left a gap in the essential cycle of transmission of knowledge and skill between the trained craftsman and the apprentice, and this hiatus has coincided with a tremendous upsurge of building activity coupled with the extensive development of new materials and techniques. Thus, the industry has at the moment, the problem of a gap in age structure, with aging but highly skilled craftsmen tending to find employment on maintenance, repairs and work other than housing, while on the other side of the gap the young post-war apprentices and journeymen are chiefly employed on housing work.

The urgent post-war need for houses has, unfortunately, made excuses for a lowering of standards of craftsmanship, and at the same time the lack of embellishment on practically all modern buildings due to the current leaning towards "functionalism" in design, has decreased the opportunities for maintaining craft skills and passing them on to the younger generation. Perhaps worst of all, the incentive or bonus scheme has been the main contributory factor in preventing the normal training and development of building apprentices, for in the hurry-burly of united gang or group efforts to achieve this or that target, the foreman or journeyman finds it difficult to take time in instructing the/
the young apprentice in the finer points, the knacks and the shifts of his craft. Nowadays one rarely sees the younger apprentice bricklayer hesitantly and painstakingly laying facing bricks to the line while the foreman or journeyman "backs in" for him, keeping up a running fire of criticism the while. There is no time for this, and the apprentice must do what he can do best within the team, usually the rough inner walling.

The education and training of the craft apprentice, for so long the function of the master-builder, has quite plainly been handed over to the technical colleges and schools. This transfer of function commenced in the 'thirties, with evening classes in carpentry, plumbing, brickwork, painting and decorating. Since the last war, day classes have been introduced and many apprentices attend for one day each week supplemented by one or two evenings on the basis of a "quid pro quo".

In England, the system of "day release" has been operated fairly successfully for ten years or so and the day students are generally far more numerous than those who are not released during the day and have to attend in their own time in the evenings. In Scotland the employers are finding it very hard to acquire the habit of releasing their apprentices for study during the day and consequently the number /
number of day students in Scotland is proportionately far below the number attending during the daytime in English schools.

The schools in Scotland provide for the training of building craftsmen on the monotechnic principle. Thus in Aberdeen, Glasgow, Dundee, Edinburgh, Cambuslang, Falkirk and other centres there are trade or craft schools which concentrate mainly on the craft processes and craft technology. In a few isolated instances provision is made for selected students to take the more theoretical studies leading to a National Certificate in Building but in general this type of advanced study is only available in the central institutions. The term "central institution " is peculiar to Scotland and describes the large, comprehensive polytechnic colleges such as the Royal Technical College, Glasgow, or the Heriot-Watt College, Edinburgh, where the Building Department is but one amongst many other departments dealing with a wide range of technologies such as engineering, applied chemistry or physics.

These central institutions give no craft instruction because this is concentrated in the craft schools which may be situated some distance away from the central institution. This separation of function between the craft school and the Building Department in the central institution is unlike most colleges/
colleges in England which are organised on the polytechnic lines described for the Scottish central institutions but go much further in that they comprehensively cover craft instruction in all departments together with the technologies to advanced level. There are one or two monotechnic type building schools in England, the Brixton School of Building, the Hammersmith School and in the provinces, the recently formed Liverpool College of Building. But these schools are vastly different to the Scottish monotechnic school for they are so much larger in scale and provide courses in building craftsmanship and technology to an advanced level, courses in building foremanship and administration and courses in professional studies leading to the examinations of the institutions of Civil Engineers, Chartered Surveyors, Structural Engineers, etc.

From this comparison of teaching institutions in England and Scotland the following points emerge:-

1. Where a craft school operates in the same area as a central institution there must be a certain amount of uneconomic duplication of accommodation, equipment and teaching staff.

2. The advanced building students in a central institution are denied the opportunity of seeing at first hand the actual craft/
craft processes in the workshops, neither can they see and examine at close quarters the tools, machines and materials associated with each craft. Many authorities concerned with the education of architects consider that a closer association between architects and craftsmen during the earlier stages of their training is beneficial to both, indeed some go further and insist that the student architect should receive some instruction in practical craftsmanship. Be this as it may, these opinions reinforce my view that full-time diploma students of building should be required to spend some time during their course in craft workshops, and the absence of these workshops in the Scottish central institutions hinders the organisation of full and comprehensive diploma courses.

3. Students in the monotechnic craft schools have no opportunity of contact with students in other industries and professions and in consequence their horizons are far too narrow.

4. The contrasting interests of the central institution and the craft school coupled with the substantial differences in status and teaching conditions are extremely unfortunate and undesirable, and make poor comparison against the English method. It is heartening to record that work is soon to start on the first polytechnic college to be built in Scotland.
in Scotland.

Most craft courses in the Scottish schools prepare students for the examinations of the City and Guilds of London Institute, taking two to three years for the Intermediate stage and a further two years for the Final Examination. After this the student may qualify for a Full Technological Certificate which is awarded by the City and Guilds of London Institute when the candidate can provide evidence of completing satisfactorily, a comprehensive group of courses in subjects allied to his particular craft.

One course of particular interest is that leading to the examinations for the Scottish Certificate in Plumbing. It is a course which has no counterpart anywhere else in the British Isles, the length of the course varies according to the education authority - in Lanarkshire it takes five years satisfactory study at a recognised centre to gain the Ordinary Certificate and another two years for the Higher Certificate. The length of course is rather less in the Aberdeen and Edinburgh districts but generally the course for Ordinary and Higher Certificate takes longer than a corresponding course of study for a Final City and Guilds Certificate. The course content includes both practical work and theory, here again there are amazing differences in course syllabuses of the few Scottish schools or colleges which offer this course.
course.

The central institutions and a few other technical institutions are recognised centres where students may prepare for an Ordinary or Higher National Certificate in Building. The National Certificate course was originally planned for the non-craft student, that is to say the builders' clerk or estimator or possibly the builders' sons, but there were never really enough students coming forward from these sources and most National Certificate students in the colleges today are craftsmen who have completed a City and Guilds course or by reason of exceptional ability have been drafted directly into the course after completing a preliminary year. The smaller colleges experience considerable difficulty in running the complete five year course which includes three years for Ordinary level and a further two years for the Higher. The difficulty is in enrolling sufficient students in the third, fourth and final year, sufficient, that is, to justify the expense of putting on the class. It is generally found that the number of students entering the course at first year level shows a marked reduction as the years go on; indeed the wastage is often appalling, with perhaps one hundred in the first year dwindling to twelve or so in the fifth year.

The National Certificate syllabuses are framed so as to give the students a comprehensive knowledge of building/
construction embracing all trades, preparation in mathematics and geometry and possibly elementary mechanics; then in the advanced years there is provision for builders' quantities and estimating, building supervision, structural work and builders' accountancy. The courses show a remarkable variation sometimes between colleges, and one is tempted to ask if the scheme is really a national one.

*National* Certificate schemes are normally the joint responsibility of the particular professional institution and the Ministry of Education in England and Wales and the Department of Education in Scotland. In contrast against the powerful institutions representing the civil, mechanical and electrical engineering interests, the Institute of Builders—a comparatively unknown organisation of master-builders—gave up its sponsorship of the building students' interests and for many years the National Building Certificate interests have been looked after by a kind of "caretaker" Committee composed of representatives from the Royal Institute of British Architects, the Civil Engineers, the Chartered Surveyors and the Structural Engineers, together with the Ministry of Education or the Scottish Department. That the Institute of Builders has remained complacent in the knowledge of these thousands of building students, farmed out to this "caretaker" Committee, is/
is, by itself convincing evidence of the apathy and ineptitude that has characterised the Institute's activities in building education during the past fifty years. In 1952 the Institute invited a selection of the larger colleges to participate in a new scheme of preparation for its Licentiate and Associateship examinations, but the restricted exemptions proposed within the scheme attracted little enthusiasm. The Heriot-Watt College did, however, indicate its formal intention to take part in the scheme, but in spite of reminders this application, which was sent in November 1952, has not been answered up to this moment of writing, February 1955! This is not an isolated example of the shortcomings of this Institute by any means; the files of all technical institutions throughout the United Kingdom could produce overwhelming evidence of the frustration and exasperation which has been experienced by education authorities in their dealings with the Institute of Builders over the past fifty years.

In this description of the education and training of the builder, this rather lengthy reference to the negligible part played by the Institute of Builders is felt to be fully justified, for there surely cannot be another industry or profession where less has been done for the education of its apprentices and students by its representative Institute, or what purports to be its representative Institute.

* First official reply received October 1955 - three years afterwards!
Some mention has been made of the system of day-release for building craft students in which apprentices are allowed to attend at a technical institution during one day each week. In England this system extends also to the National Certificate students but it is a remarkable fact that part-time day courses for the National Certificate in Building are not available at Edinburgh or Glasgow, consequently students in these large cities wishing to take such a general building course have to attend during the evening, three times weekly for five years.

This lack of part-time day National Certificate course seems to be due to the Scottish employers' preference for the more direct benefits gained from craft courses, and of course, the division of interests between the central institutions and the craft schools has something to do with it, for the central institutions are mainly preoccupied with full-time courses.

There are two centres offering full-time diploma courses in Building in Scotland. The Royal Technical College has a four-year course qualifying for a Diploma and Associate-ship of the College and the Heriot-Watt College has a three-year course qualifying for the Diploma of the College and in addition a Higher National Diploma; both Colleges make provision for students spending part of their course on the building site, preferably in an assistant supervisory capacity.
capacity.

The advantages of university education for the building industry were fully appreciated in the Report on Training for the Building Industry issued by the Ministry of Works in 1942, but nothing has been done to implement the recommendations set out in that Report. Meanwhile, the universities continue to provide degree courses in engineering, commerce, household and social science, etc., yet, with the exception of the Building degree course at Manchester, there are no opportunities for promising boys from secondary schools and technical schools to obtain a university training in what is probably the most fundamental of all arts or sciences.

The complicated nature of building operations today, together with the tremendous development and application of modern scientific research in the industry, require men who have received training in the fundamental sciences, in costing and managerial techniques and in the wider and more liberal aspects of their calling than is possible in the somewhat narrower technical institution course.

A limited number of courses in management or building foremanship are available in the Scottish technical colleges, but they are confined to classes in the evenings only because building contractors, unlike their counterparts in the engineering and other industries, will not release their foremen to attend day classes.
Scotland has lagged behind England in supplementing the normal provision of bursaries or scholarships for full-time building courses. In England, independent financial assistance is given to building students by numerous local organisations of master-builders including those in the South of England, London and Lancashire, but in the whole of Scotland, only the Edinburgh and District Association of Master-builders has been persuaded to award a bursary of £150 towards a two-year attendance in the Heriot-Watt College's diploma course. It is quite possible that the Scottish system of separate trades contractors has much to do with this for these separate contractors have their own organisations and their interests are firmly based on the particular craft, plastering, slating, etc., that they represent.

It is, of course, fair to say that the recently disbanded Building Apprenticeship Training Council has awarded several scholarships tenable at universities or technical colleges and Scotland has been represented on this Council to the extent that a fair proportion, a total of three awards, altogether, have been made to Scottish students. Of these three scholarships, one recipient took the B.Sc. degree in Building Technology at Manchester University and the other two elected to take the Diploma course at the Heriot-Watt College.

Taking/
Taking one year with another, the total number of full-time building students in the Scottish technical institutions rarely exceeds a total of thirty, with perhaps ten new students coming in each year. Remarkably few of them are builders' sons; many are craft students who have done well in the evening classes for National Certificate and have managed to obtain a bursary award from their local education authority. Occasionally, indeed very occasionally, a secondary student with his Scottish Higher Leaving Certificate will be attracted to a career in the building industry and will enrol for a full-time course, but this is very rare. Headmasters in the Scottish public schools have little notion of the prospects in the building industry for a bright student, or for any student, and when finally, a boy from one of these schools does appear before a Building Selection Committee, he is supported usually by an observation from his headmaster in the terms "this boy tries hard but is not particularly bright, I recommend that he is a suitable type for the building industry"! This is the attitude of mind that has characterised educational authorities for many years and which has restrained and bedevilled building education for so long.

The constant introduction into the building industry/
industry of new techniques, materials, scientific data and new methods of cost analysis and job management demand building executives possessing a first-class intellectual equipment, and these notes on the training and education of the builder suggest that the higher grades of training have not advanced at the pace required. This lack of pace seems to be much more noticeable in Scotland for it has been shown that only a mere trickle of students are coming into the full-time building courses and most of these are craftsmen who have graduated through evening classes and gained entrance to the full-time courses on the basis of a National Certificate rather than a Scottish Higher Leaving Certificate.

These notes have also shown that much ground has been lost in the matter of day-release courses in Scotland, particularly part-time day courses for the National Certificate in Building. Craft training is most essential in this vast industry employing many craftsmen, but technicians are units in an organisation or team, and the men who must control and lead this team need the more general education embodied in the National Certificate Scheme so that they may understand the problems which arise in all the trades and be able to apply an open and unprejudiced mind to the application of new methods and new materials.

* The 1956 White Paper on Technical Education has confirmed this."

Cement and Concrete

Since the war, cement has been used in ever increasing quantities; demand has constantly outstripped supply, particularly in Scotland where local production is sufficient only to meet about one quarter of the demand in Scotland. This means that the balance must come from England by sea and during the post-war years this source of supply has been far from dependable; when the English cement manufacturers could not meet the demands of the English contractors the supply to Scotland was severely restricted and this meant that foreign cement had to be bought instead. These foreign supplies came from Belgium, Germany and Sweden, and generally the cost was higher than English cement. The quality was quite good, but few of the Scottish contractors had confidence in it and they avoided its use wherever possible.

The main criticism of the foreign cements applied to the wide variations in strength. These variations were particularly noticeable in the Belgian cement which produced cube strengths at three days varying from 1800 pounds per square inch to 3,000 pounds per square inch. The lower figure exceeded the minimum strength prescribed in B.S.12/
B.S.12 of 1600 Ib/sq. in. for mortar cubes at three days
and I have found this to be so in at least a dozen
commercial tests that I have made on Belgian cement.

In house-building, the cement used in brickwork
mortar is far greater in volume than the cement used in
rendering or in concrete floors or foundations. According to
a recent Ministry of Works Report, the economic amount of
cement for building a normal brick house up to 1,000 square
feet in area is, apart from factory-made components, about
6 to 7½ tons. This figure assumes that lime/cement mortar
is used in proportions of approximately two parts of lime
to one of cement. Lime/cement mortar has been the subject
of searching tests by the Building Research Station and the
results indicate that the mixture of lime, cement and sand
in proper proportion makes for a mortar which is more flexible
and has less shrinkage on setting than the mortar made of
cement and sand only. Special masonry cements containing a
mixture of Portland cement and hydrated lime, aluminium
stearate, or granulated slag have been developed commercially
in the U.S.A. and at least one type is available in this
country.

The great difficulty is in overcoming the deep-seated
prejudice of the building contractors against the mixture
of lime with cement, for many of the brickwork and masonry
contractors/
contractors in Scotland and elsewhere have the unshakable conviction that lime and cement have chemical properties which are opposed to one another and have a neutralising effect on each other when mixed together. In the face of such blind ignorance it is small wonder that someone thought of mixing the lime and cement together as a commercial production and selling it to these "doubting Thomas's" under the reassuring title of "masonry cement".

The original material which Joseph Aspdin, a North Kent building contractor, patented as "Portland Cement" in 1824 has been steadily improved by constant experiment and use. Developments between the two world wars concentrated upon rapid-hardening and high-alumina cements and now, these post-war years have witnessed the development of an extensive range of new types of cements to meet the new and varied circumstances in modern building work. Quick setting cements are now manufactured which cause concrete to set within twenty minutes of placing; low-heat cements are produced for situations where it is essential that the heat generated during the hydration of the cement should be reduced; experiments are well advanced in the production of an expanding cement, so that sufficient expansion is present during the setting of mortar or concrete to more than counteract normal drying shrinkage. The application of/
of these expanding cements to underpinning operations or to 'in situ' piles is particularly interesting - for example it has been found that concrete made with expanding cement, and used to underpin a wall, has applied a force of about 20 tons between the wall and a pile below the concrete.

Also in the experimental stage are waterproofed cements which are claimed to produce a concrete which is much more impermeable than concrete mixed with standard Portland cement. But of the cements which have been mentioned, none are specially applicable to house-building operations, except of course the masonry cement, and perhaps the most important development at the moment - one which may have an effect on housing costs - is that concerned with the use of pulverised fuel ash to replace part of the cement in concrete. In the United States and Canada this pulverised fuel ash is being used widely in mass concrete work to replace 20% of the cement used in normal concrete. According to American, Russian and German authorities, concretes in which up to 20% of the cement has been replaced by this ash have proved to have a rather lower initial strength than ordinary concrete, but the concrete gradually builds up in strength until, at three months, it is equal to that of the ordinary concrete.

Fly/
Fly ash, the short name given to pulverised fuel ash, is being used by the North of Scotland Hydro-Electric Board in the concrete for dam construction and other works where large masses of concrete are being placed. The addition of fly ash to the cement achieves two important objectives; in the first place setting is retarded and the heat generated during the hydration of the cement is reduced, and secondly a considerable saving in cost is effected.

Tests carried out in February 1955 on cement mixed with fly ash are described below. These tests were made in my laboratory at the request of an Edinburgh civil engineering contractor who was shortly to commence the construction of a large hydro-electric scheme involving very large masses of concrete.

The fly ash and cement were mixed in the proportions 2 : 8 and 2.5 : 7.5 and standard mortar briquettes were made up for tensile tests at periods ranging from 12 to 36 hours after gauging. The results, presented in graph form, indicate a reduction in strength when compared with the control briquettes but the advantages of retarded setting together with a saving of cement may be considered to outweigh this difference in strength.
EFFECT OF THE SUBSTITUTION OF FLY ASH FOR PART OF THE CEMENT CONTENT OF MORTAR BRIQUETTES.

(Mix 1 : 3 Cement : Standard sand by weight)

Specimens made and cured as per B.S. 12 : 1947 except no water immersion.
Water/cement ratio 0.325.

TIME (Hours after gauging when tested).
Bulk delivery of cement is a new means of reducing the cost of concrete by eliminating paper bags and the waste associated with their use. The cement may be delivered in special containers on ordinary lorries, in tipper lorries or in tankers fitted with special delivery hoses. This method of delivery is, of course, more suited to very large housing schemes or engineering works where there are good permanent storage facilities.

Coloured cements are now produced by manufacturers in two grades. The first grade includes cements in a small range of colours suitable for footpaths and similar situations where the coloured cement is used throughout the thickness of the concrete. The second grade of cement is manufactured in a much wider range of colours including the lighter shades and is for use in finishing and external application only. A British white Portland cement is also manufactured which complies with the requirements of B.S.12 for Portland cement.

These bright-coloured finishings and washes could be used far more on Scottish housing than they are. The appearance of vast areas of housing in the everlasting drab self colour of harling is quite unnecessary in this age of improved and colourful materials.
The concrete which was used by the Regency builders was little different to that which the Romans used. Lime, sand and hard core were often mixed dry and shovelled, without wetting, into a trench which contained water; or sometimes the dry concrete was placed in a dry trench and then slaked with a lime grouting. This lack of development over nearly 2,000 years of building compares strangely with the tremendous improvements which have been made in concreting methods and mixes since Monier, the French market-gardener, experimented with wire mash as reinforcement for flower pots in 1867.

Considerable development was seen between the wars when cement became cheaper; building contractors began to employ concrete more in the foundations to simple buildings and also entered the specialist field of reinforced concrete which hitherto, had been occupied by firms doing nothing else but this kind of work. This progress was, however, negligible by comparison with the progress which has followed a period of intensive post-war research.

To attempt to describe all that has been done in the field of advanced concrete technology over the past ten years would provide material for several books and I propose to limit this description to a summary of recent improvements in/
in concrete as a building material for housing purposes, with special emphasis on reduced costs.

When the building contractors started to use concrete they considered it to be a very elementary operation and invariably entrusted the work to labourers. They worked on a very simple formula of a 4:2:1 mix, turned thrice dry and thrice wet, and applied this formula indiscriminately to all types of work and all kinds of concrete aggregates. If the reinforcement was fairly closely spaced then the concrete was well watered so that a sloppy mix consistency was obtained and the concrete could find its own way through the reinforcement without assistance and would also find its own level more easily. On many jobs today, an inspection would reveal pretty much the same state of affairs except that there would be a powered mixer instead of hand-mixing. There would still be the 4:2:1 mix by volume applied to different aggregates and the water would still be added by guesswork.

Many of the better organised firms are, however, employing methods of concreting in line with modern practice and are obtaining the strengths required at far less cost. Probably the first application of research has been to regulate the ratio between the water and cement used; this is based on tests which have shown that, for given materials and/
and conditions of manipulation the strength of concrete depends on the ratio of the volume of mixing water to the volume of cement, so long as a workable consistency is obtained.

The next important application of modern knowledge is the weigh-batching of concrete materials. This dispenses with the old method of proportioning the materials by volume and instead, the different materials are proportioned according to their weight. Unfortunately, weighing arrangements are not available on many concrete mixers and comparatively few contractors have so far invested in proper weigh-batching machines. Of course, good concrete can be economically produced when proportioning by volume, but the method is so open to the human element of slackness and in consequence design stresses have to be raised to guard against this.

Compaction of concrete by mechanical vibration has been proved to add considerably to the strength of the finished concrete. The concrete which is to be vibrated can be mixed with less water and from what has already been said about the effect of the water/cement ratio on ultimate strength it will be obvious why vibration is a cost reducing factor in concreting operations. Under laboratory conditions the comparative/
comparative results obtained from the making and testing of
two cubes of identical concrete are very striking, and
rarely fail to make an impression on students of building
science or concrete technology.

Perhaps the most important of all recent changes
due to
in concreting technique is the realisation that the standard
specifications for concreting work have been unsatisfactory
in that they have always called for a nominal mix supported
by a specific cube strength and slump, irrespective of the
particular type of aggregate which is to go into the concrete.
The trend now is to refrain from tying the contractor down
to lengthy and often meaningless specifications, and in
place of these requirements he is required to produce a
concrete of a specified minimum strength together with such
other requirements the particular job may demand. Subject to
these requirements the contractor may use the available
aggregates to his own mix design embracing whatever water/
cement ratio or method of mixing he cares to adopt.

This method of applying the principle of "quality
control" to contractors should simplify site supervision
considerably and put an end to the everlasting conflict
between architect and contractor on the suitability of
materials and whether they comply precisely with the terms
of/
of the specification. One must admit that it is a little exasperating to a contractor who is a party to a contract that specifies Tay sand in concrete, and is prevented by a zealous clerk of works from substituting a sand which is available within close reach of the work situated in the Edinburgh area. The clerk of works is not interested in the ultimate strength of the concrete which is likely to result from the admixture of the disputed sand; he is concerned only with the fact that the specification is being flouted in the contractor's interests. He is also playing safe, for it is well known that the official who always keeps to the regulations will never be taken to task, even though the client may, in the long run, have lost time and money through an unhappy relationship on the site between architect and contractor.

Since the Ministry of Works gave the lead to the abandonment of the standard specification for concrete by incorporating the "quality control" clause in over sixty contracts since 1952, it has been quite noticeable that civil engineering and building contractors handling the larger constructional works have been given the same freedom to design their own mixes for concrete. Quite often the contractor does not have the specialist staff competent to design mixes or else he feels inclined to shift the responsibility/
responsibility, so far as he is able, to an independent specialist. In this connection I have acted in a consultant capacity on several occasions in the design of a mix for concrete which has to meet specific strength requirements, and a short description is set out below of the mix design figures for a Scottish hydro-electric dam which is now nearing completion.

Mix Design

Fine aggregate (as supplied by contractor) complying with B.S. 882:1944.

Coarse aggregate (as supplied by contractor).

Note:—this aggregate was supplied separately in various grades of single sized aggregate. A representative sample of graded aggregate was requested and when received this had the appearance of having been made up from single sized aggregates. When combined, the sample contained an excessive quantity of material passing the ¾ in. diameter sieve. Accordingly, the coarse aggregate used in the mix design was made up from the single sized aggregate originally supplied in the proportion shown in the particulars set out below. These gradings comply with B.S.882:1944.
Method:

First the fine and coarse aggregate was tested for compliance with B.S. 882:1944. Then preliminary test cubes were made with constant proportions of fine/coarse aggregate, constant workability but with 10% and 20% less cement respectively so that some advance indication is given of a minimum strength that will serve as a basis for the design.

Following the preliminary aggregate and cube tests, careful consideration is given to the characteristics of the aggregates, the question of marginal allowance for the normal variation in the strength of works cubes, the degree of workability required for the particular work, and whether compaction is by means of vibration or not. Bearing these points in mind, proportions and water/cement ratio are worked out from graphs and a series of test cubes made from a selected range of designs. The following figures were obtained from 24 test cubes representing a planned system of variation in the proportions of mixing and water/cement ratio.

**MIX REFERENCE NO. 1(A)**

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<th>$\frac{3}{8}$</th>
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<th>W/C Ratio</th>
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<td>2/3</td>
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**MIX 1(A) AT 7 Days**

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**MIX 1(A) AT 28 DAYS**

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<th>$\frac{1}{3}$</th>
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### MIX 1(B) AT 7 DAYS

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</tr>
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### MIX 1(B) AT 28 DAYS

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<tr>
<td>1(b)</td>
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### MIX REFERENCE No. 2(B)

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<th>$\frac{1}{6}$</th>
<th>$\frac{1}{6}$</th>
<th>W/C Ratio</th>
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</thead>
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<tr>
<td>4</td>
<td>1 $\frac{1}{2}$</td>
<td>3</td>
<td>2/3</td>
<td>1 $\frac{1}{6}$</td>
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### MIX 2(B) AT 7 DAYS

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<th>Wt.</th>
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### MIX 2(B) AT 28 DAYS

<table>
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<th>Tons</th>
<th>Crushing Stress</th>
<th>Wt.</th>
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<tbody>
<tr>
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<td>6188.9</td>
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</tr>
<tr>
<td>2(b)</td>
<td>99</td>
<td>6157.8</td>
<td>19.6</td>
</tr>
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</table>
The significance of the effect of the water/cement ratio on the strength of the concrete is very obvious when the results for cubes 2(A), 2(B) and 2(C) are compared. The difference in strength of 3,639 lb/sq.in. between concrete mixed to 0.36 W/C ratio and that mixed/
mixed to 0.48 W/C ratio is remarkable, even when due allowance is made for the advantages of vibration under laboratory conditions.

These results show that properly designed concrete mixes to a laid down minimum strength can lead to a reduction in costs. The Ministry of Works section dealing with questions of concrete quality and production has recorded reductions in cement content varying from 10% in cases of hand-placed concrete designed for a failing stress of 3,000 lb/sq.in. at 28 days to 40% in an instance where high quality concrete was made for pre-stressed work. Savings of 15% to 20% of cement are quite normal in well designed and compacted concrete and there are other small savings in the cost of materials together with the advantages of better workability and a resulting concrete which is denser and less liable to frost damage or shrinkage cracks.
Lightweight aggregates are helping to counteract the disadvantages which have always been associated with the use of concrete for housing purposes. Normal concrete at approximately 144 lbs per cubic foot is a dense material which has a low thermal insulation value and encourages condensation; the lightweight aggregates produce a concrete within the range 50-90 lb/ft³, and the concrete gives considerably improved thermal insulation.

The chief lightweight aggregates used in this country are clinker, foamed slag, expanded vermiculite and expanded clay. Peat has been used experimentally as a concrete aggregate; a croft was built in the Isle of Skye sometime after 1950 and the walls were constructed of peat concrete cast in situ. The Building Research Station representatives watched this work very closely and the main criticisms which emerged were (1) there was a difficulty in finding suitable supplies of peat near at hand to the sites where buildings were needed (2) the maceration of the peat was a costly operation and (3) drying shrinkage of the peatcrete walls was excessive.

The most outstanding development in concrete for house-building since the war has been in the use of "no-fines"/
"no-fines" concrete. This is not a lightweight concrete, the fine aggregate is simply left out and the mixture of coarse aggregate and cement forms the honeycombed structure which effectively resists capillary penetration of moisture and provides a good key for rendering and plaster. The thermal insulation value depends on the particular aggregate used.

Scotland has played the leading part in the development of "no-fines" concrete in housing work ranging from three-storey to eleven-storey blocks. The very nature of the concrete with its rapid drying properties and suitability for continuous pouring up to considerable heights has assisted the creation of a constructional technique of 'in situ' walling which has had a marked effect on the reduction of cost.

Pre-stressed concrete has not, so far, had very much influence on the reduction of house-building costs, but it is quite possible that the mass-production of pre-stressed concrete floor joists, roof panels or floor panels might compete in cost with wood members. Further consideration will be given to this when an examination is made of constructional techniques.
It is a strange thing that a reputable building contractor who employs only the best craftsmen on his brickwork, joinery, plumbing, etc., is quite content to entrust his concreting work to a labourer. This does not mean to say that he will employ any labourer, for quite often he will have a particular man who has always looked after the concreting work for him and is paid a penny or twopence above labourer's rate for doing so. But it seldom happens that these men have any special ability in the technology of concreting other than what they have picked up on the job or what they have learned from previous failures.

Occasionally the concreting work will be supervised by the joiner or bricklayer foreman, but it does not follow that either of these craft foremen will have more than a rudimentary knowledge of concrete work. Indeed I remember one particular instance where the bricklayer foreman, an excellent craft foreman, used granite chippings containing an excessive amount of quarry dust in a large factory floor. The concrete was mixed to a sloppy consistency, tamped and trowelled until all the dust rose to the top;
top; then after three weeks or so of anxious and puzzled probing the whole floor was taken up and relaid. Fortunately, but only by pure chance, the dust was missing from the aggregate the second time, and in spite of a repetition of the excess of water, tamping and trowelling, the concrete hardened more or less satisfactorily. The wastage of time, materials and money resulting from the combination of these most elementary mistakes was bad enough, but the great tragedy is that the particular foreman is still unable to account for the failure of the concrete.

The urgent and pressing need for proper training and some form of certification of concrete supervisors, to enable them to carry out efficiently and intelligently the processes connected with the production and placing of concrete, has existed for many years, in fact ever since the builder started making concrete. An Edinburgh consulting engineer has told me that his design stresses for concrete may vary more than 20 lb/sq. in. according to the estimated degree of efficient supervision; this means that for every building containing concrete work and where efficient supervision is uncertain, the designer must play safe and provide heavier, wasteful sections with increased steel.
steel reinforcement adding to the cost. Here then is something tangible, a sure way to cut down building costs, simply by training men to mix good concrete and place it correctly. Yet there has been active opposition from employers and trades unions alike, to proposals for setting up courses of instruction in concrete technology for site supervisors or potential supervisors. This opposition springs from the conviction that a labourer with a recognised qualification in concrete practice will regard himself as a craftsman and will demand a craftsman's status and pay.

Fortunately this misguided and narrow-minded opposition has been overruled by the persistent demands of certain organisations concerned with reinforced concrete and precast concrete, together with a number of building educationists and a few of the more enlightened contractors. The City and Guilds of London Institute has, in response to this demand, organised a recommended course of study leading to an external examination for a Certificate in Concrete Practice. More than a score of technical institutions in Great Britain offer this course, and the first written and oral examinations were held in 1955.
Rubber

The application of rubber to building purposes was, until recently, confined to the sheathing of electrical wiring. Now there are wider applications including expanded ebonite for thermal insulation, floor coverings, latex rubber mixed in concrete, rubber additives to oil paints and rubber used for sound insulation.

Rubber flooring is generally available in sheets or in tiles cut from the sheets. It provides a hard wearing, flexible and colourful finish but the expense of this material rules its use out for house-building. However it is possible that future development of the natural rubber latex/cement compositions may result in lowered costs.

It is claimed that the addition of rubber to oil paints improves the flow of the paint and eliminates the brush marks which are often left behind in the non-rubberised paints. A special paint preservative has been developed which contains chlorinated rubber, the object of chlorinating the rubber being to assist the paint to take up a larger proportion of rubber and also to make the rubber non-inflammable.

Rubber inserts in formwork for concrete have been particularly useful. They allow intricate dovetailed chases to be formed and many difficult ductings for stressing wires.
PLASTICS

The first transparent plastic appeared towards the end of the nineteenth century when cellulose nitrate, known as celluloid was used in stiff collars and moving films. The pronounced inflammability of this early plastic ruled out any question of its development for building components and it was not until methyl methacrylate was produced in the 'thirties that the familiar Perspex emerged as a likely building material. Its initial development was of course, in the aircraft industry.

There are two main types of plastics, the thermoplastic and the thermosetting. Thermoplastics retain their flexibility and can be softened by heat, but the thermosetting type of plastic moulds once only into permanent shape. So in the field of plastics we have two very different kinds of basic material, one flexible, the other hard and rigid; the flexible plastics are eminently suited to the manufacture of piping for domestic services, for agriculture and for brewing services, while the hard-setting plastics are best adapted to situations where they must fulfill a constructional function or where heat resistance is essential.

The stages in the progress of the introduction of plastics/
plastics into the building industry can perhaps be summarised as follows:—first the small moulded electrical fittings, then the various types of door furniture followed by the more prosaic lavatory seat, after this the wide development of polythene piping for cold water services and finally the evolution of reinforced plastic sheet materials, extruded sectioned constructional units and the combination of synthetic resin adhesives with wood waste in the manufacture of chip-board.

Perhaps the most interesting and outstanding example of the use of plastics in Scottish buildings has been in the two new schools built in the Edinburgh area in 1954/55, particularly the design by local architects of the school at Drylaw where external and internal walls were constructed in hollow plastic panels filled with a glass wool packing. Windows were built into the plastic panels before leaving the factory, doors were constructed of the similar hollow plastic section to that in the walls and all plastic surfaces were finished in bright and pleasing colours. In certain parts of the structure the plastic wall panels were loadbearing in that they supported part of the roof structure; other novel features included the ability to house electric wiring within the hollow wall spaces. 

(26)
Extruded piping made from polyethylene (better known by the trade name "polythene") has had a limited use in this country for some years now but plumbers are still very critical of it and generally loath to use it. This piping is accepted by some water authorities as suitable for water supply and domestic cold water services and it is also covered by a British Standard (B.S.1972); so far however, the main uses of polythene piping have been in agriculture, brewing and the chemical industries rather than in new buildings. It is quite likely that this plastic piping will be used more in building work as prejudice is slowly overcome; the advantages over copper or lead piping are fairly considerable - the long continuous lengths, the smooth and colourful appearance, resistance to corrosion, frost and furring up. It is indeed most unfortunate that polythene tubing is unsuitable for use with hot liquids for this rules it out as a material for hot-water services and being so, it is unlikely that plumbers will quickly or easily accustom themselves to working with two different pipe materials side by side, demanding different tools and techniques.

Present development in plastics for building purposes/
purposes seems to be concentrated on the laminated plastic sheets and on glass-reinforced translucent plastic sheets. These translucent sheets are made from polyester resins reinforced with glass fibre and they are made in a similar form to Perspex but have rather special properties for diffusing light. They can be obtained in any of five fast colours and are made to the exact dimensions of as many as fifteen kinds of corrugated and trough-section roofing to match corrugated iron, asbestos-cement, aluminium or steel sheets. Unfortunately the fire resistance qualities of this roofing material are not high and while the L.C.C and certain other local authorities have permitted its use in buildings, they have laid down certain fixing conditions to ensure compliance with fire regulations.

As with most new materials, exhaustive tests have been made to prove the durability of plastics, the resistance to compression and tension, to abrasion and temperature movement; but these tests are only laboratory tests and pilot field tests and are often inconclusive. Accelerated weathering tests have been made in which samples of the material are placed on the outside of a wheel which revolves once in one hour and is subjected to an infra-red light, an ultra-violet light and finally water treated with chemicals; the test going on night and day. Yet even such a test as this cannot effectively/simulate xx
effectively reproduce the action of wind, rain, sunshine, frost and atmospheric influences on exposed material. The opinion of many chemists and physicists is that a plastic tends to "craze" or form minute surface cracks after five or ten years exposure to weather. Then the rainwater penetrates the cracks and freezes, or it deposits injurious chemicals from town atmospheres; finally the bond in the filling or reinforcement in the plastic material breaks down and with the plastic in a state of partial disintegration the weather resistance and strength of the component is reduced considerably.

This problem of use when a new material is introduced is ever present and quite often risks have to be taken, otherwise few new materials could ever be introduced into the industry. The experience of plastics in the electrical engineering industry has been that plastic insulating materials have stood up satisfactorily to more than twenty years usage; and gear wheels made from thermosetting plastics have also given good service. There is, unfortunately, little information on the use of plastic materials in external walling and we can only wait and observe. It is probable that these external wall sections will remain weather-resistant and durable for forty to fifty years and, after all, it is not unlikely that education authorities in 2006 will want to remove these schools and build others of contemporary design.
Where plastic pipe is used in building work it is necessary to remember that the thermal expansion is much greater than the thermal expansion for metal. In a 20 ft. length, plastic pipe may expand as much as .022 in. per degree Fahrenheit, according to the diameter of the pipe. It follows from this that care must be taken to allow for this thermal movement wherever the pipe is laid or fixed. In trenches the pipe must be "snaked" so that there is a certain amount of slack that can take up without damage to the pipe. American manufacturers recommend that suspended installations of the soft flexible polyethylene pipe should be supported by hangers, each/twelve diameters of pipe size up to 1 in. diameter and eight diameter spacings for pipes above 1 in. diameter.

There has been criticism in some quarters that plastic pipe can be nibbled away by rats, also that there is a danger of the plastic material having a toxic effect on potable water. I took the first point up with I.C.I. Ltd. and was assured that their experiments had proved conclusively that a rat would never attack plastic piping unless it barred its way to freedom. Regarding the second criticism, a two-year research programme carried out by the National Sanitation Foundation at the University of Michigan has shown in a preliminary report that there is no toxic effect on water.
The Decline of the Use of Stone in Scottish House-building.

For centuries past, stone has been the main walling material in Scotland. Houses were generally built of solid rubble walls with worked dressings around openings and an ashlar front. Over the years a deep rooted tradition of stone masonry developed and flourished up to the commencement of the 1914-18 War, then after this the diminished use of stone became very noticeable.

The first signs of the decline were seen in the rough-casted rear walls of houses between the wars. Then the flank walls and all other walls except the front were built in brickwork and finally in 1939 the only stonework on housing was the standard bungalow front. This was particularly noticeable in Edinburgh due to thousands of house buyers "settling" to escape from the traditional Scottish tenement or flat, yet at the same time being most insistent on showing a stone front, at least, to the visitor or passer-by.

In 1945, when house-building started again, the most desperate need for speed ruled stone out as a walling material. Precast stone and concrete slabs were used when bricks were scarce and occasionally compared favourably with brickwork from the standpoint of cost. But stone was never considered again as an economic walling unit, even when housing schemes were adjoining/
adjoining the stone quarry. The high cost of building in stone was confirmed beyond argument by a Building Research Station special survey in 1950. It was found that an ordinary three-bedroomed semi-detached house of about 950 square feet superficial area, built in rubble walling, cost at least £300 more to build than a comparable house of brick construction. A house built in ashlar walling cost £450 more to build in S.Scotland and £750 in N.Scotland.

The reasons for this high cost of stone building are many and varied. Generally speaking, the cost of building plain stone walling is about 50% more than brick walling, but the cost of the stone itself is the chief contributory cause of high cost. Approximately three tons of stone have to be hewn from the quarry to produce one ton of saleable building stone and yet there have been few changes in quarrying methods since 1918. At the same time it is fair to point out that outside of Scotland, progress has been little better and the few new techniques which have been developed are difficult to apply in Scotland where the sandstone is hard and the beds dip sharply.

The prospect of the development of Scottish sandstone in any form of new constructional technique does not appear to be bright. The B.R.S.Report concluded that the future of the industry is likely to lie in the mass production of simplified components for many small buildings; but the Report did not include an estimate of the number of masons required for/.
for such an expansion of the industry. Clearly, the number of mason apprentices entering the industry and the number of masons employed at present by Scottish private builders *(estimated at 2000)* does not encourage one to think that the mason labour force would be adequate to cope with any expansion of stone production, however slight. Of course, there are many masons in Scotland who have been engaged on brickwork for the past ten years and there is the possibility that they would, in the event of the resuscitation of stone building, return to their own craft.

It is rather surprising that the B.R.S. Report, together with most other enquiries of this kind, have failed to consider the question of repairing and maintaining stonework, and to compare the cost of such repair and maintenance with the upkeep of brickwork. Few stone buildings stand for more than a hundred years without, at some time or another, incurring expense on repairs, particularly in the larger cities where harmful deposits from a polluted atmosphere break down the structure of the stone. Brickwork lacks the aesthetic appeal of stone in a country so noted for its buildings of native stone, yet a brick made from a dependable clay requires any maintenance, apart from occasional pointing.

*Technical Information Officer, M.O.W. Edinburgh.*
This short commentary on the decline of the use of stone in Scottish house-building has, perhaps, concentrated too narrowly on house-building and has failed to present the entire picture of natural stone construction as applied to all types of buildings. The Hydro-Electric Board are making every endeavour to revive the stone quarrying and stone building industries in the North and West of Scotland by using local stone wherever possible in building power stations, sub-stations and staff accommodation. The Board have built or are building sixteen generating stations of stone and some ninety staff houses; all these buildings are, of course, in the more distant areas in the North of Scotland.

The main sources of stone have been the three quarries - Greenbrae Quarry, Covesea, near Burghead, Moray. Tarradale Quarry, near Muir of Ord, Ross-shire, and Tain Quarry, Ross-shire. The Glen Affric power station at Fasnakyle has been faced with rubble masonry of yellow sandstone from Greenbrae Quarry, the Luichart power station has been built in stone quarried at Tarradale and two other power stations at Torr Achilty and Glascarnoch have used stone from the Tain Quarry. Many other power stations have also been built in natural stone and the largest of all was the new diesel station at Kirkwall in Orkney. This large undertaking/
undertaking was built in the traditional masonry style of Orkney, in squared random rubble, and over 1600 tons of blue whinstone from Walliwall Quarry, Kirkwall, were used in the entire construction. The total saving effected by using stone was estimated to be £600 plus £2,000 saving in structural steel which would have been required in a brick or concrete building.

In 1954 the County Council of Ross-shire, the Forestry Commission and the Hydro-Electric Board agreed to carry out a joint scheme for building a village of 28 stone houses at Contin, near Strathpeffer, the stone to be supplied from the Tarradale Quarry. The Hydro-Electric Board is also building other groups of stone houses at Fort Augustus, Glaearnoch and other places in the Highlands.

From this reference to the construction of power stations, etc., it will be obvious that the Hydro-Electric Board are doing everything they can to resuscitate the stone quarrying industry and excellent work has been done to this end. The reaction of Mr. Thomas Johnston, Chairman of the Board, to the findings of the Building Research Station's "Survey of Building in Sandstone in Scotland" is understandable when he severely criticised the Report for containing/
containing what he described as "wantonly inaccurate and prejudiced statements".\(^{(24)}\)

The particular statement which offended Mr Johnston was the one which read "Whatever the type or design of building and wherever in Scotland it is built, it costs more to build in stone than in brick or concrete", and this, quite clearly from what has been stated about the Kirkwall power station, is not an accurate statement. But the opportunities for stone-building to enter into competition with brick and concrete only occur in far flung outposts such as Orkney and the more inaccessible parts of the Highlands, where the cost of transporting bricks or cement is prohibitive.

* It will be interesting to have a note of the cost of the 28 houses at Contin when they have been completed. A comparison of the final cost with houses built of imported bricks should be worth inclusion in this research study. In the view of/B.R.S. Report I consider it more than probable that the houses will cost considerably more than if they had been built in brick or concrete blocks. The use of natural stone in the massive walls of a power station is an entirely different proposition to the use of stone in house-walling.

All the evidence seems to weigh against a revival in the use of natural stone for house-building, and there can be little/

* In reply to a written request for this cost information in Oct.1956, the Board was unable to help.
little prospect of an increase in the use of stone in buildings other than houses when Northumberland stone is chosen for the National Library of Scotland; and Edinburgh University has to go to England for the stone in the front elevation of an Examination Hall.

**Brickwork in House-building.**

Scotland has few deposits of good brick-clay and this is probably the main cause of the slow development of the use of brickwork. The first use of the slender clay resources was seen in the red pantiles covering many of the nineteenth century country cottages in various parts of Fife, the Lothians and the mid-western counties. A few handmade bricks were manufactured in unusually large sizes, sometimes six inches wide, four inches thick and twelve inches long. They were used in plastered internal partitions. Handmade bricks of the more usual sizes were also made in fairly substantial quantities over a hundred years ago and were used generally for internal partition work. Nowadays when demolition contractors pull down these old partitions they fail to appreciate what a wealth of colourful material they have in these lovely old bricks in colours ranging from pink to plum and they are invariably consigned to the brick crusher. One day perhaps, some enterprising contractor will use water and wire brush on a few thousands of these bricks and sell them for contemporary internal faced walling at a handsome profit!
The few sources of good clay in Scotland occur in the Central Area and the bricks produced are of good quality, hard and dense, and eminently suitable for loadbearing walls in civil engineering works or in positions below ground level where moisture and frost resistant qualities are paramount. For these reasons, the house building industry uses very few of these bricks and instead is dependent on the local production of composition bricks from clays extracted in the process of coal mining or on bricks made from spent shales mixed with other aggregates and bound by cement and/or lime.

These composition and cementaceous bricks are generally of a poor quality. The composition bricks have an extremely unpleasing appearance and quite often the variation in strength, colour and size of a "firing" or kiln of bricks from another "firing" in the same brickyard is very great indeed. The bricks may vary in colour from a pasty yellow with dark vertical bars to dark red or plum, the disfiguring vertical bars being remarkably constant through most of the colour range. In size the variation between an underburnt brick and one which has been very close to the fire may amount to half of one inch in the length and one quarter of an inch in the depth of the brick.

The following copy of a test report which I recently made on a sample number of composition bricks will serve to show/
show the variation in compressive strength:

**Clay Composition Bricks.** (Tested November 1954)

**Group No. 1.**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Failing Stress (lb. per sq.in.)</th>
<th>Average Failing Stress (lb. per sq.in.)</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>2281</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2130</td>
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</tr>
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<td>4</td>
<td>2192</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2017</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2070</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2130</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1461</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1278</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2100</td>
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<td>11</td>
<td>1522</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1491</td>
<td></td>
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**Group No. 2.**

<table>
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<th>Failing Stress (lb. per sq.in.)</th>
</tr>
</thead>
<tbody>
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<td>2550</td>
</tr>
<tr>
<td>7</td>
<td>1946</td>
</tr>
<tr>
<td>8</td>
<td>2055</td>
</tr>
<tr>
<td>9</td>
<td>2685</td>
</tr>
<tr>
<td>10</td>
<td>1781</td>
</tr>
<tr>
<td>11</td>
<td>2055</td>
</tr>
<tr>
<td>12</td>
<td>2166</td>
</tr>
</tbody>
</table>

1834.3 lb./sq.in.

2064.6 lb./sq.in.

The variation in the bricks making up the first group ranges from 1278 lb./sq.in. to 2281 lb./sq.in. and this difference/
difference of 1003 lb/sq.in. in twelve bricks selected at random is **impressive** enough. Yet, in the second group of tests the average failing stress was higher, but the variation between the weakest and the strongest was 1286 lb/sq.in. Clearly, such wide variations in strength give cause for concern if not alarm, and there are signs that the manufacturers are not unmindful of this. Also, the failure of a number of the bricks at stresses below 1500 lb/sq.in. is a sign of poor quality or insufficient firing.

Generally speaking, the margin of safety with reference to the compressive strength of bricks in conventional walling is quite considerable, but these tests are carried out on bricks which have their frogs filled with 1;1\(\frac{1}{2}\) cement and sand mortar reaching a cube strength between 4,000 and 6,000 lb. per sq.in., in order that the compressive load shall be evenly distributed over the entire bedding area of the brick. Thus, this British Standard Test relies on the frogs being filled in the actual walling, and this reliance is often misplaced. In house-building, bricks are commonly laid frog downwards in the interests of speed and ease of laying, and it is the generally accepted view that the frogs do not get filled in such circumstances. So it is that wall pressures fall unequally and more intensively on/
on the outer rim of the brick, and these local stresses are bound to be high. Actually how high is a question which is difficult to answer because so many complex issues stand in the way of precise calculation, for example the slenderness ratio of the wall, eccentric loadings, unbalanced point loadings, etc.

It is possible that the margin of safety is often dangerously narrow and with the recent introduction of deeper U-shaped frogs by the manufacturers of Fletton bricks, coupled with the express intention to lay the new type bricks frog downwards, it will be necessary to make new tests and maybe write in more exacting requirements into the existing codes of practice.

As a comparison with the test figures for composition bricks I have taken a representative sample of twelve ordinary clay bricks, manufactured in Scotland and applied similar compression tests. The results are set out below:

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Failing Stress</th>
<th>Average Failing Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3590</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3679</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3561</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3590</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3532</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3590</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3770</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>4035</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3590</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3679</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>3561</td>
<td></td>
</tr>
</tbody>
</table>

The figures show a closer relationship between specimens and a much higher average strength.

Although/
Although these composition bricks vary so greatly and are so often of poor quality the demand still exceeds the supply. Lorries form queues outside the brickworks in the early hours of the morning and are sometimes turned away empty when the day's production is exhausted. Builders must make their requirements known at least one month before the bricks are wanted and are then given an allocation of so many on certain days throughout the month.

With such a "sellers' market" it is small wonder that the brickmakers lag behind continental brickmakers in the development of perforated bricks or hollow clay blocks. The scarcity of clay; the variation in size on burning, the low thermal insulation value of solid clay bricks,—these are all good reasons for a change from the conventional British brick. The introduction of voids into the bricks would make for more efficient firing from less fuel and the lighter bricks or blocks could be transported and handled more cheaply.

An encouraging development in Scottish brick production took place in December 1954 when a new kiln at Brora in Sutherland was fired for the first time. Its capacity was estimated to be six million bricks a year, the bricks being of a quality and colour suitable for facing work.
work. The deposit of brick clay in Brora is, as far as is known, the only one of its kind in Scotland and in quality it is comparable with the Lancashire or Oxfordshire clays. So for the first time, the Highlands are producing a good type of facing brick.

It is possible that the restricted supply of bricks in Scotland may soon be supplemented by bricks made from an entirely new basic material - pulverised fuel ash. This ash is a waste product of the burning of pulverised coal in power stations all over the country. It is an extremely fine ash and has been described as being very similar to the volcanic ashes, or pozzolanas which the Romans mixed with calcined limestone in order to produce cement.

In the experiments which have been made by the Building Research Station the fuel ash has been mixed with a plastic clay in the proportions ash to clay of roughly 85% to 15%, and bricks of good quality have been produced. At the time of writing, experiments are being made in the Edinburgh district on pulverised fuel ash taken from Portobello Power Station where the disposal of the ash has for some time presented something of a problem. There may be some difficulty in transporting the clay to the ash or the ash to the clay but if, as has been estimated, about ten million bricks per year can be made from the annual yield/
yield of ash from one large power station then it should be well worth while finding the means to surmount such difficulty.

Bricks made from concrete have been produced in Scotland, mainly for use as facings. A market is readily found for them because clay facing bricks must generally come from England and high transport costs quite naturally turn the architects questing for cheaper substitutes.

The concrete brick can be produced in very uniform shapes and sizes, and by dipping or dashing processes a pleasing range of colours can be obtained. But my own observations and laboratory tests have shown that there is a danger of quite large drying shrinkages coupled with low compressional strengths as compared with good-class clay facings. Also there seems reason to doubt the permanence of colouring.

The selection of a suitable facing brick for the panel walls in the latest extension of the Heriot-Watt College presented some considerable difficulty owing to the need for economy. The difference in price between English clay facings and locally manufactured concrete facings was very considerable and before the selection was finally made, a series of tests was made in my laboratory/
laboratory in accordance with British Standard 1257:1945 (Methods of Testing Bricks). The selection of test data set out below adds point to what has already been stated about drying shrinkage and compressive strength.

Test Reference - College Extension.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Total Drying Shrinkage</th>
<th>Percentage Shrinkage</th>
<th>Average % Dry Shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.1008</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.0090</td>
<td>.0995</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.0097</td>
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<td>.10144%</td>
</tr>
<tr>
<td>4</td>
<td>.0122</td>
<td>.1355</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>.0077</td>
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<td></td>
</tr>
<tr>
<td>6</td>
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</tr>
<tr>
<td>3</td>
<td>.0065</td>
<td>.0684</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crushing Load (Tons)</th>
<th>Crushing Stress (Lb/sq. in.)</th>
<th>Average Crushing Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.10</td>
<td>1174</td>
</tr>
<tr>
<td>2</td>
<td>24.75</td>
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<td>18.00</td>
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<td>20.00</td>
<td>1166</td>
</tr>
<tr>
<td>12</td>
<td>19.00</td>
<td>1117</td>
</tr>
</tbody>
</table>

1137 lb/sq. in.

The drying shrinkages recorded and the compressive failing stresses/
stresses place the particular bricks in Grade B and as such they are unsuitable for an external load-bearing wall. The first six bricks, with an average drying shrinkage of 0.1%, that is to say an average shortening in the length of roughly 0.01 or one hundredth of an inch, came out very badly. One can imagine the consequences of such movement in say, a twelve foot panel containing sixteen bricks end-to-end in a course, and each brick reducing one hundredth of an inch, making a cumulative total of 0.16 in. - quite a sizable crack. Small wonder that the expense of clay bricks was finally accepted.

The limitations on colour, imposed by the use of natural clays, are narrow, and the effect of time and weather on brickwork does not help. There is a real need for a wider range of colour in our buildings and nowhere more than Scotland is this need more obvious, for everywhere throughout the length and breadth of this northern country the sombre grey to brown stone or harling prevails and seldom indeed is it that the Scottish scene is enlivened by any other colour except, perhaps, for the occasional russet or red pantile or the clean wash of a coloured cement. One can but hope that an enterprising brick industry will turn one day from its 'sellers' market' and take note of the progress which has been made on the Continent and in the U.S.A. in developing semi-glazed clay products in pleasing and durable colours.
HERIOT-WATT COLLEGE, EDINBURGH

BUILDING DEPARTMENT
(Head of Department — Norman C. Sidwell, M.Sc., M.I.Struct.E., A.R.I.C.S.)

TEST CERTIFICATE AND REPORT  No. HW/832/56.

Specimens of Clay Brick.
Submitted by Arnot McLeod Co. Ltd.,
Russell Road.

Date of Receipt  2/11/56
Order No. or Reference

Specification  B.S.S. 1257

Data and Results
The six samples of Brora bricks submitted were tested in accordance with B.S.S.1257 with the following results.

<table>
<thead>
<tr>
<th>No.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4060 lbs. per sq. inch.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4390 &quot;   &quot;   &quot;</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4500 &quot;   &quot;   &quot;</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7030 &quot;   &quot;   &quot;</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5350 &quot;   &quot;   &quot;</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4560 &quot;   &quot;   &quot;</td>
<td></td>
</tr>
</tbody>
</table>

Average compressive strength

4981 lbs. per sq. inch.

Signed ..........................

5/11/56.

(Note:— This is/very satisfactory result with regard to compressive strength. The colour of the specimens submitted was quite good and reasonably uniform).
EFFECT OF DRYING SHRINKAGE IN CONCRETE BRICKS.

Drying shrinkage crack in a concrete brick panel wall in a factory at Musselburgh, Nr. Edinburgh. There were similar cracks in all the other panels throughout the building.
The technique of prefabrication in the building industry was introduced when the first brick was made and used in a wall. Everything, almost, that the builder uses is prefabricated - drainpipes, cement, ironmongery, tiles, etc., all are manufactured in a factory and then brought to the building site. Even completely prefabricated houses are by no means a twentieth century development for they were used in the early days of colonial settlement when, in 1794, C.B.Waldstrom suggested in his "Essay on Colonisation particularly applied to the Western Coast of Africa" that wooden houses of a sectional type should be sent out from Europe to provide temporary shelter until proper towns could be built.

The ordinary person thinks of prefabrication in buildings as a post-war phenomenon, as something that was meant partly to take up the slack in the factories when the war drive ended, and partly as a temporary means of house-building until the post-war demand was met. This has meant that this important technique has never been taken seriously, and has been regarded as something temporary and not quite up to the standard of the good old traditional type of building.

The questions that have to be answered in any consideration of the application of prefabrication to house-building/
house-building are:-(1) do prefabricated building components perform the same function and last as long as the site-built components?, (2) can the prefabricated parts be assembled and finished so that the completed building is of a pleasing appearance? (not losing sight of the fact that it is the house-owning or house-renting public which has most to say about this), and (3) does prefabrication reduce the absolute cost of the house to the consumer?.

In answering the first question we must distinguish between the prefabricated components such as baths, doors, windows, etc., and the less commonplace components such as wall sections, roofs or completely prefabricated plumbing units. We are not concerned with the first group because those items have been used in house-building for so long now that they have largely displaced the site-manufactured article. In the second group, prefabrication has been mainly applied to walling units of all kinds, ranging from light wooden frames with a weather resistant outer skin, a cavity or filling for thermal insulation and an inner lining, to storey height precast concrete panels. There are indeed, many hundreds of different types of prefabricated wall units and a critical examination of a selection of these units will be made at a later period in this study; in general it can/
can be said of these walling units that they often achieve a higher standard of thermal insulation and weather resistance than the average brick cavity wall and there has been little evidence so far of structural instability. It is the long term test that is needed to confirm whether or not the new walling units can maintain a good standard of weather resistance over the years, and in the meantime the question of durability must remain unanswered.

It can be stated that there is already a problem of maintenance in connection with certain of the totally prefabricated houses which were erected in the immediate post-war years. Local authorities are finding that the usual allowance of £11 for the annual maintenance of each house is being exceeded in many cases and in Edinburgh the excess expenditure has become such a serious matter that representations are to be made to the Treasury for funds to cover the excess. The £11 allowance includes about £3 for management costs and the remaining £8 is soon swallowed up on very minor items of repair.

The chief instances where maintenance is needed on the temporary prefabricated houses in the Edinburgh area include the replacement of metal rhones which, originally of light gauge material, have deteriorated to "paper thin" thicknesses.
thicknesses. Then, in the houses which have asbestos-cement wall panels a certain amount of treatment with special pigmented sealing paints has been necessary to overcome moisture penetration through porous walls. Also, the Scottish local authorities have had to spend money on securing roofs which have a tendency to lift in the face of gale force winds.

Many repair problems have been set up by the use of poured concrete walls and the close relationship of lightweight and dense concretes which have different drying shrinkages and varying degrees of thermal movement. This movement cracks plaster finishes and in Edinburgh it has been found necessary to cut the plaster back and to fix scrim over the offending joints.

One critical comment made by an Edinburgh official in charge of large-scale maintenance of prefabricated houses was that the very nature of the prefabricated components operated against the carrying out of very minor repairs, because in most cases the particular damaged part had to be replaced completely. The answer to this of course is that new parts should be readily obtainable and low in cost, but according to the information given to me the very reverse/
reverse of these conditions is usual, the spare parts being practically unobtainable and very costly when available.

It is important that spare parts for prefabricated houses should be readily available and that the total replacement cost (taking into account the saving in time of skilled labour) should compare favourably with the cost of the conventional site repair of non-prefabricated fitments. It is no use saving initial cost of a house by including a prefabricated plumbing unit costing, say, £95 for the unit and £5 for installation, if the entire unit has to be replaced whenever the first minor repair becomes necessary.

Maintenance costs on the permanent types of prefabricated houses have been encouragingly low, and on the "no fines" houses I have been told that repairs have been almost negligible. It is, of course, too early to draw precise conclusions from this information, for obviously the houses have not been up very long; the paintwork and finishes have to withstand the test of time, and the interiors have to withstand the test of tenant! Local authority officials are unanimous in declaring that maintenance/house property varies considerably, according to the type of tenant - and that the variation is greater where prefabricated interiors (plastics, wall-board linings, etc.) are concerned.
The "teething" stages of prefabrication will be bound to reveal many shortcomings and it is quite likely that only a few types of walling units will entirely escape criticism. The development of a new building technique by using prefabrication is vastly different to the development of, say, a light diesel engine for a private car. The first prototypes of the car can easily be tested in every conceivable way - from rigorous bench tests to endurance trials in the Canadian Rocky Mountains. But the building component can only be tested properly in the building itself, and the manufacturer cannot wait fifty years or so before he goes into production, though he may - like the first producers of concrete roofing tiles - have to wait twenty years before demand justifies full production.

Every attempt to introduce a new prefabricated unit into house-building is beset by this immediately unanswerable question of durability. One of the greatest obstacles to the development of prefabricated buildings is the reluctance of the building societies to advance loans on what to them seems "experimental" building. This reluctance has been reinforced by the increases in the Bank Rate during 1955 and in any case, the resources of the building societies are fully taken up in advances on the traditional types of brick built houses.
Passing on to the second question in this consideration of prefabrication—the question of the appearance of the finished work—it seems true to say that the early post-war prefabricated bungalows, built by the thousand in hideous sprawling excrescences on the British countryside, have done more harm to the development of the technique of prefabrication than any other single factor. Taken by themselves, certain of these one-storey houses are quite presentable, and if properly sited with a reasonable amount of space between they can be suitable for small groupings. But they, like the 1918 "prefabs" which stood for twenty years, were only meant to be temporary and like most temporary buildings, little trouble was taken with their siting, and the creation of screens, focal points or background by tree-planting was rarely undertaken.

The prefabricated houses which followed these temporary buildings were more often partially prefabricated, usually with some form of framing filled in by panels and topped by a conventional roof. Wherever possible the wall units were designed to be finished with a rendering which disguised the prefabricated nature of the wall and made comparison with the conventionally built house very difficult. In fact, this seems to have been the aim of most producers of houses with factory-made walling units, and/
the reason for this is that most people like to live in a
house of the type which they have been accustomed to seeing
and living in throughout their lives. It is for this reason
that most Scottish people yearn for the good old houses with
three foot thick stone walls - even in the face of evidence
that this thickness of solid stone is far less weather
resistant than a well built 11 inch cavity wall of brick.

For these reasons then, most of the so-called
non-traditional houses have a conventional tiled roof; this
does seem unfortunate when every effort has been made to
prefabricate the building otherwise. I am surprised that
the simple mono-pitched roof has not found favour more than
it has, for it would surely lend itself to a prefabricated
form of panel construction on a light wood framing jointed
in the new resin adhesives. The panels could be given a
two-layer facing of bitumen bonded felt before leaving the
factory and the final layer and finishing coat could be
applied when the light trusses and panels had been fixed.
Something of this sort was done on the roofs of the 1918
"prefabs" insofar as felt surfaced panels were made up in
the works before going on to the site.

From what has been said, it seems that buildings
assembled from prefabricated components can and do have an
appearance which is acceptable to most people - but only so
far as they resemble traditional type houses.
The final query in this consideration of the application of prefabrication to house-building concerns cost, "does prefabrication reduce the absolute cost of the house to the consumer?". It is not possible to give a short answer to this question because cost is affected by a number of factors, the most important being demand.

A prefabricated building component is made in a factory in much the same way as a car. The design is carefully executed, prototypes are made to precise measurements and thoroughly tested, then machines are "tooled up" and special jigs are made in preparation for the mass production of the particular component. All this painstaking design, experiment and testing takes a long time and it is very expensive, so expensive that it is essential that thousands of the finished article must be "demanded" by the industry, otherwise these initial costs would, if spread over a smaller number of articles, have the effect of forcing up the price to the point where it exceeds the price of the site made component or element.

The advantages of factory methods of production are many. All work is carried out under cover with the means of non-stop production throughout 24 hours per day, with no enforced/
enforced stops for bad weather or reduced periods of daylight during the winter. Every possible process is mechanised, effort is reduced to a minimum and a sequence of operations can be worked out which ensures a steady output all the time. Tea breaks are organised systematically, punctuality is assured by efficient timekeeping arrangements, raw material stocks are maintained at the right level and in the right place and scrap material is properly accounted for.

Against these advantages may be set heavy overhead expenses, far higher than obtain usually in a building contractor's organisation. Rates of pay for factory workers are usually higher than for building operatives, particularly when bonuses are allowed for. The components have to be temporarily stored, then packed and transported to the site; the raw materials have also to be transported to the factory and storage space provided. Finally there is the requirement already mentioned - for a large and sustained demand to justify the heavy expense of setting up the manufacturing process.

In 1945 it was not a question of cost economy which caused the Minister for Post-War Reconstruction to commission large numbers of prefabricated small houses.
It was the pressing need for speedily erected houses that gave prefabrication its first big chance; thousands of small bungalows, totally prefabricated, were supplied to local authorities, and one might have supposed that the manufacturers would have made the most of this opportunity for demonstrating the economic advantage of the mass produced, prefabricated house as against the established methods of construction. But there was nothing reminiscent of the early, mass-produced Ford car prices about the post-war prefabricated bungalows; at approximately £1600 each, exclusive of site costs, they were far more expensive than they should have been, and their sole advantage was the saving in time as compared with the traditional brick-built house.

These fantastic prices were paid because there was no other alternative while factories were pleasing themselves whether they should prefabricate houses or join in the rush to make consumer goods to meet the pent-up demand of war-workers' earnings and soldiers' gratuities. Nevertheless, it is probable that substantial profits were made on the sales of these early prefabricated dwellings and, as a consequence of this rather short-sighted policy there is a marked resistance on the part of/
buyers to the factory-made building. We now read that a two-bedroom house of 750 sq. ft. is available, completely erected and connected to services, for £1,250. Such a house can be supplied in six weeks and erected in a few weeks. A similar three-bedroom 1,000 sq. ft. house is available for £1,600. These prices were quoted in the journal "Prefabrication" early in 1955 with the note that "the prefabricators have thus shown that they can make a substantial contribution to the problem of reducing the cost of houses while maintaining quality."(3)  

This extract from the editorial of a technical journal devoted to prefabrication would appear to be out of touch with present day building economics, or with present demand. For clearly, the time is now past when £1,600 will be paid by local authorities or private buyers for a prefabricated house which offers the single advantage of being capable of erection in six weeks.

The main advantages appear to lie with partial prefabrication so far as cost is concerned. The experimental houses recently erected at Canterbury at a cost of about £1,000 each, were constructed on the cross-wall system with light prefabricated panels, front and back, and the accommodation provided was of the three-bedroom, four person/
person type house. It was estimated that these houses were built for approximately £64 less than a comparable two-bedroom house in traditional construction. The figure of £1,000 is certainly an encouraging sign of a downward trend in housing costs and the system of cross-wall construction appears to strike the right balance of the dual use of ordinary traditional brick walling and prefabricated panels.

It is quite possible that we shall see further reductions in housing costs when the building operatives get down to the task of setting a high standard or rate of production in return for the incentive of high wages. In his talk on The Advantages and Disadvantages of the Prefabricated House (Royal Sanitary Institute, 1951), Sir Alfred Bossom gave an instance where prefabricated buildings in London cost the same per cubic foot as similar buildings in New York, yet in the United States they were completed in a half to two thirds the time taken in Great Britain. This was due to the incentive of high wages in the U.S.A. where craftsmen are paid more than double the rates obtaining here.

From what has been said about the influence of prefabrication on the reduction of building costs it does seem that the way to lower construction costs may well lie in/
in the combination of traditional methods and prefabrication. There are many house types, popularly called "semi-traditional", which already incorporate prefabricated external wall units or prefabricated interiors, and they are being produced at improving rates and for less cost than ever before. The elevations are also showing a much needed improvement and in greater variety; the ending of Department of Health control over non-traditional house designs, in January 1955, has tended to stimulate the production of new types of semi-traditional houses because the manufacturers may now trade directly with private and local authority buyers.

All the signs appear to point to a further lowering of costs in housing employing this combination of the factory product and the site function as represented by load-bearing cross-walls, underbuilding and special footings on sloping or awkward sites. The demand for houses at any price is slackening and the prefabricators must keep their organisation fully occupied by improving production or cutting profits in order to gain the advantage over the fully traditional method of house-building. If this happens, as indeed it must, the consumer will benefit from a reduction in price due to the use of prefabrication, and the question under consideration is answered.
An outstanding example of the conscientious pre-planning of a building job has quite recently been provided by one of this country's largest and most progressive contractors, who was the nominated contractor in a large multi-storey housing scheme. In this large project it was decided to employ a substantial measure of prefabrication involving a number of quite complicated precast concrete sections. In addition to this it was proposed to embody in the structure certain new forms of plumbing, ventilation and smoke disposal. Also there was to be an almost complete elimination of wet plaster in the internal finishes; some form of precast or pre-formed external wall facing was required. Finally the principle of prefabrication was to be extended to include the timber floors separating the upper and lower storeys of the individual maisonettes.

The photograph shows a full-scale prototype of a complete maisonnette that was erected by the contractor on a spare piece of ground behind his Research and Development Department.
In this full-scale reproduction every component part was carefully incorporated into the building. The prefabricated precast concrete floor sections were manufactured by the vacuum process and an extremely smooth and regular surface was achieved. The sections were about 12 ft. by 4 ft. and vee joints were used between sections to absorb any slight movement due to moisture or drying shrinkage.

Mass concrete crosswalls were cast 'in situ' and required only a fine skim of plaster to present an adequate finish. The prefabricated timber floors were made up in six complete panels and, like most of the components in this full-scale "mock-up" they were placed in position by crane in the same way as they were meant to be placed in the actual building. The flue system for the slow-combustion stoves was built into the 10 in. concrete crosswall together with a "shunt" form of ventilating duct.

The "single stack" plumbing system was built into the 10 in. "in situ" crosswall and every working part of the system was thoroughly tried out, even to the extent of cantilevering supporting scaffolding out from the wall to support appliances which, in the completed building, would be expected to discharge into the built-in stack-pipe.

Such a preliminary investigation as this, involving such painstaking and expensive experimental operations, is indeed a praiseworthy example of preplanning.
It is evident that other countries are using prefabricated houses or components, for Great Britain has been exporting prefabricated buildings in increasing quantities since 1949, when prefabricated buildings to the value of £80,000 were exported. This figure increased to £7,000,000 in 1952 when British output of such buildings was greater than that of any other country in the world.

The use of prefabricated timber sections in small house-building in America has been going on for a long time, and the manufacture of house "packages" is very highly organised. In the U.S.S.R., an extensive network of building industry factories has already been created and is being considerably expanded; these factories are producing precast concrete frames and floor members as well as complete staircases and wall sections.

In France the use of prefabrication has been stimulated by changes in the taxation system imposed on building firms. Before the changes were made, buildings or parts of buildings manufactured off the site were liable to a 15.35% tax levied on the selling price of all manufactured goods. Now, considerable progress is being made in the development of complete panels incorporating secondary fittings, outer woodwork, hot-water piping, etc.
Other countries including Czechoslovakia, Poland, Norway, Sweden, Belgium and Ireland are developing the prefabrication of standard building elements, and most reports indicate that the new methods are tending to reduce costs. Of all the countries mentioned, America is probably the greatest user of wholly prefabricated houses - in one year the housing subsidiary of the U.S. Steel Corporation, (United States Steel Homes, Inc.), produce 8,000 houses and employ over 1,700 workers operating on three eight-hour shifts, six days a week.

In concluding this consideration of prefabrication, no clear cut statement can be made concerning the long term future prospect for it. There is, at the moment, a great deal of slack to be taken up in the building industry, and prefabrication is only one way of taking up the slack. There are other improvements which are overdue, notably in the field of management and site organisation and also in the initial planning of every building job by architect, builder and surveyor as a team. And these improvements may well effect significant economies in housing costs when the established traditional methods are employed.

Whether, in the final analysis, prefabrication will save cost is a question which may take ten years to answer; my own opinion is that the use of prefabrication will increase progressively in the long term future.
MODULAR COORDINATION.

The need for the standardisation of structural building elements and for the general acceptance of a yardstick or module, against which all buildings may be compared and planned, has always been admitted as highly desirable in the interests of building economy. Yet, surprisingly little has been done to coordinate the thousands of small building elements so that they fall readily into place within the framework of the building for which they are designed. Manufacturers simply go their own way in the matter of sizes, wallboard makers favour a four ft. width, window frame producers have many different widths but work most frequently to a lft. 8 in. dimension. Copper pipe is made in 18 ft. lengths, bricks may be anything from 8½ in. to 9½ in. in length and the entire range of building equipment varies considerably in size and shape.

These remarkable variations in the dimensions of building elements are not confined to Great Britain; in America there are window manufacturers who still make their windows in more than 450 stock sizes, and regional variations in favoured ceiling heights are much the same as in Britain. In New England for example, there is a tendency towards a low ceiling, even lower than our generally accepted 8 ft. standard, yet in the Southern States it is usual to provide higher ceilings. Here the situation is reversed,/
reversed, for it is in the North/where the higher ceiling is called for. But the variation is still there and 8 ft. wall boards are not suited to the 8 ft. 4 in. or 8 ft. 9 in. floor to ceiling heights.

All this is not to say that architects are not fully alive to the urgent and pressing need for some form of rationalisation in building. In January 1947, the Council of the R.I.B.A. approved the formation of a study group to consider and report on dimensional standardisation. Almost at the same time the British Standards Institution was responsible for the setting up of a technical committee on Modular Coordination and following the report of this committee the Building Divisional Council of the British Standards Institution recommended that a small team be formed to apply further and more detailed study to the problem of modular coordination.

In 1953 the Modular Society was formed "to reduce building costs by promoting research, experiment, development and discussion concerning the use of the module in the design and construction of buildings and in the manufacture of building materials." Shortly after this important development the teams were formed by the Building Research Station and the British Standards Institution to examine in detail/
detail the problem of evolving a module for building components. The work of the B.R.S. and the B.S.I. has been carefully integrated and one of the most useful results of this work has been the proposal to the European Productivity Agency that this investigation of modular coordination ought to be undertaken by European countries in the interests of increased productivity in the building industry. This proposal has resulted in active participation by eleven European countries.

The Modular Society is in close contact with the work of the B.R.S. and the B.S.I. It includes in its membership practically all those in this country with practical experience of modular design and in addition its membership includes experienced representatives from overseas. Professor Ciribini, already mentioned in this thesis is an active member of the Society and is doing possibly more than any other Italian to introduce modular design into Italian building.

The great difficulty in any international consideration of modular planning is to secure international acceptance of a module. It can be well understood that if Britain cannot see eye to eye with America or even a close neighbour like Belgium on a vital defence module such as the/
the standardisation of the calibre of small arms, then it is less likely that there can be agreement reached quickly on modular coordination in the various nations' buildings.

This problem of achieving international unity was fully appreciated by the Organisation for European Economic Co-operation, and the United Kingdom was given the task to study the methods of modular coordination adopted by different countries and to make recommendations for international agreement on the size of a module which might be acceptable to all. Quite obviously it was apparent to the Organisation that if agreement could be reached then substantial benefits would be realised from the interchange of building materials between the different countries.

In the approach to international agreement the first major difficulty that arises is due to the research on the very problem by the individual countries. For a number of years now, certain countries have been experimenting with various modules, for example in America there is a strong leaning towards a basic module of 4 in. with all other dimensions a multiple of this module. In the German investigations the one metre dimension has been favoured and all building dimensions are factors of the metre; there are, in/
in fact, two modules favoured by the Germans - a 12.5 cm. and a 10 cm. module. The 12.5 cm. dimension appears to have been related to the 1.25 metre planning grid adopted in Germany during the war and the 10 cm. module is in line with that favoured by other metric countries. In this country the Modular Society has strongly supported the adoption of the 4 in. module and is compiling a Modular Catalogue in which is presented building components that are generally available and have appropriate external dimensions in whole multiples of this basic module of 4 in. measured to centres of joints or joining members.

In France, M.le Corbusier's "Modulor" is basically two sets of numbers in the form of a geometric series and having a relationship to anthropometric dimensions. This module is very complicated to understand and for this reason its suitability for operation by the building industry is doubted by many experts on modular coordination.

These variations in the basic dimensions adopted by the several countries serve to show the extent of the problem facing those who are trying to obtain some measure of agreement internationally. Taken separately, the various countries are each doing good work in the interests of modular coordination. The Belgians, for example, realised early/
early in 1938 that increased industrialisation required the standardisation of dimensions, and they even went so far as to pass a Bill prohibiting the standardisation of any new item in the building trade unless it complied with a module of ten centimetres. Before the war an experiment in modular coordination was made when the Luchtbal residential development was planned at Antwerp. Some 1,800 houses were planned in a neighbourhood unit and the general intention was to use a prefabricated industrialised technique wherever possible and to relate all component sizes to a module.

It was soon found that the habit of building to traditional methods was hard to overcome and further difficulty was encountered when the local authority insisted that the contractors at all stages of the work were selected on the basis of the open tender. This ruled out the practicability of organising industrialised production through the medium of a nominated contractor. Nevertheless, it was found that the first 200 houses in the scheme were erected more economically as a result of modular planning and well-organised workshop production of components.

In Sweden, modular coordination on a ten cm. basis was established several years ago and it is noteworthy that the initial investigations were financed wholly by the National Association of Manufacturers.
For some time now the Germans have applied modular planning to their very considerable housing problem. Like the Belgians they have introduced regulations requiring all new housing proposals (ranking for subsidy) to be based on the module. In 1953 and 1954 nearly one million houses were built and it is claimed that they were all related to the modular system; these houses were built mainly of bricks or blocks in a conventional manner and little effort was made to develop new forms of walling. At the same time, however, there was a great deal of concentration on the production of standard units and assemblies corresponding with the planning grid.

The planning grid was to the accepted 10 centimetre module and room sizes were generally determined by "preferred dimensions" based on anthropometrical data but conforming with the plan grid lines. Considerable simplification was obtained by limiting the range of room sizes, house depths, ceiling heights, stair sizes, roof gradients, etc. and as a consequence of this simplification, component parts of the houses such as rafters, joists, lintels, etc. could be cut or made up to standard lengths. The economies resulting from this German application of modular planning have been claimed to be substantial, amounting to as much as 20% saving on the cost/
cost of comparable houses.

These claims have been discounted somewhat in the Report issued by a team sent to Germany and representing the Association of Building Technicians. In this Report it was forthrightly stated that the German authorities did not claim that the saving was due entirely to modular coordination — in fact the bulk of the saving was attributed to improved site organisation, to the rationalisation of working methods and to the simplification of the variety of components used in construction. I must say that I find it difficult to attribute the simplification of components to anything else other than to standardisation through modular planning, though I would be prepared to agree that the credit for any saving in cost might be due in a large measure to improved site organisation.

The A.B.T. Report also referred to the module adopted in Germany and claimed that the team had established that the 12.5 cm. and 10 cm. modules (reported by W. Allen of the B.R.S. and mentioned earlier in these notes as being used jointly in Germany) had in fact never been used in practice and existed only on paper. The Report went on to state that only the 12.5 cm. module was used in practice.

These conflicting statements, all appearing in the official organ of the Modular Society, obviously need to be/
be resolved by an authoritative German statement. However, it is quite evident, even from these contradictions, that a substantial proportion of German house-building is conforming to modular measurements and, moreover, it is evident that some cost saving is resulting from it.

The American Standards Association has followed up the early studies of Heath and Benis on the choice of a module by choosing the 4 in. dimension as a convenient basis for the standardisation of building products. It was considered that the 4 in. module was small enough to permit a reasonable amount of flexibility in design and, at the same time, was in line with the sizes familiar to architects and builders everywhere. Also, the 4 in. module approximated very nearly to the 10 cm. dimension adopted by most countries using the metric system. Ten centimetres are equivalent to 3.937 inches.

Before modular coordination was applied to American building the usual brick size was 3½ in. by 8 in. by 2½ in., but a modular brick now in production is 4 in. by 8 in. by 4 in. This increased thickness of the brick is claimed to cut down cost inasmuch that two courses of the modular bricks take the place of three of the old type, consequently replacing one complete bed-joint and effecting distinct economies in labour costs. The estimated saving is 25%.
25% in the cost of the mortar and a further 20% saving in labour cost. These figures were given in a Study by the Bureau of Labor Statistics of the United States Department of Labor and it was stated in this Study that although the modular brick used an increased volume of clay the cost of the bricks had not followed the rate of increase. It was calculated that for a 1000 ft. super of walling the new 8 in. by 4 in. by 4 in. bricks numbered 4,500 as against 7000 of the ordinary American size, and the cost per thousand of the modular bricks was $51.50 as compared with $45.00 for the non-modular bricks.

There is also a Swedish modular brick which is rather larger than the ordinary sized brick in Sweden. Its length is 26.7 centimetres and has been chosen so that three brick lengths make up 100 centimetres and thus tie in with the 10 cm. module. In inches the brick is roughly 10½ in. by 5 in. wide by 4 in. course thickness and it is clearly much larger than the American modular brick. At the same time, however, it must be appreciated that the ordinary Swedish brick is nearly ten inches long.

This consideration of modular brick sizes in other countries leads to what is perhaps the most fundamental question to be answered in this country before any real progress.
progress can be made towards modular coordination in building materials and construction.

Brick dimensions as they exist in Britain today vary a little between different regions, but the common size may be said to be 8½ in. by 4½ by 2½ in. with an approximate volume of 104 cubic ins. without frogs, cells or perforations. The weight varies according to the nature of the material between seven and a little over nine pounds. When allowance is made for jointing, the brick length is 9 in., and four lengths are required to make up a dimension which is a multiple of the basic 4 in. module adopted by the Modular Society. With a slight reduction of the joint thickness it is possible to make 4½ brick lengths fit a 3 ft. 4 in. planning grid.

It is in the course measurements of the existing brick types that difficulty occurs in relating measurements of brick walling to the 4 in. module. Bricklayers customarily build to a gauge rod on which the successive courses are marked, and the gauge measurements are determined usually by the foreman bricklayer having regard to the wallplate or wallhead height, the practicable thickness of joint according to the type of mortar, the function of the wall (facing, loadbearing, etc.). Sometimes it is possible to set out the gauge measurements so that seven courses build exactly to a height of two feet, but more/
more frequently the best height for seven courses is 1 ft. 11 in. or perhaps 1 ft. 11\frac{1}{2} in. and clearly this will not tie in well with any multiple of a 4 in. module less than 7 ft. 8 in. It might seem a simple enough operation to use a slightly increased joint thickness to enable the brickwork to be built to two ft. multiples but this would entail a substantial increase in the quantity of mortar used with a consequent rise in material and labour costs.

Wall thicknesses, to relate to a 4 in. module, should be measured so as to include final finishes. Here the existing 8\frac{1}{2} in. by 4\frac{1}{2} in. brick is a little nearer the mark, for a 9 in. solid wall plastered both sides should be about 10 in., i.e. equal to 2\frac{1}{2} times the module. But the 4\frac{1}{2} in. dimension is no use for a modular relationship in partitions, whether pointed or plastered, though two 4\frac{1}{2} in. walls plus a 2 in. cavity and both sides 1\frac{1}{2} in. for wall finish will make up a total thickness of three modules of 4 in.

If brickwork in this country is to be related to a module of 4 in. there must be a change in the present sizes and there can be little doubt in anyone's mind that whatever new range of sizes be decided upon it must apply generally to the whole country and not be subject to the excessive size variations now existing in different parts of the country.
The choice of the length of a modular brick is clearly limited to 8 in., 10 in. or 12 in. The Americans have favoured the 8 in. length, in Sweden they have chosen the 10\textfrac{1}{2} in. dimension and a little over a year ago Mr. M. Hartland Thomas, the Secretary of the Modular Society, wrote about a proposal for modular bricks in three lengths - 3\textfrac{11}{16} in, 7\textfrac{3}{4} in. and 11\textfrac{3}{8} in. (suggested by Mr. A. L. Osborne, F.R.I.B.A.). These measurements allow for joints and bed to bring the finished wall component up to 4 in., 8 in., and 12 in.; a 12 in. thick wall can be built in Flemish or Flemish "Garden Wall" bonding but not in any form of English bonding. The 8 in. size is suitable for an 8 in. thick wall in any bonding arrangement usual for the existing size of bricks.

It was suggested that these modular bricks should be perforated instead of using frogs, to the extent that the 12 in. brick would weigh about the same as the ordinary brick. As to this I agree that any modular brick should be perforated in order to reduce weight but I am doubtful whether the reduction would be quite as much as Mr. Thomas suggested when he wrote about this design for a modular brick. This point will be discussed later in these notes.

The course height of a modular brick could be 2 in. or 4 in. inclusive of bed, or it could be a dimension between/
between 2in. and 4in. that divides into 8in. or 12in.

The smaller 2in. dimension would be aesthetically pleasing when used as a facing brick but this advantage would be greatly outweighed by the disadvantages of increased handling and the additional mortar required for a 50% increase in bedjoints.

The Structural Clay Products Institute in the U.S.A. has developed a brick called the S.C.R. brick, 12in. by 6in. 2/ by 2 3in. thick which builds three courses to 8in., but generally the Americans favour the 4in. course height. The modular brick introduced by Mr. Thomas of the Modular Society also builds to 4in. courses inclusive of bed and it seems that this dimension is probably the most ideally suited to modular building.

So far, in considering the length and height of a modular brick, the overriding factor has been the need to relate the brick to the 4in. module. It is also necessary to do this when considering the breadth of the brick but it is equally important to see that the breadth dimension is related to the human capacity to grasp and move the brick with one hand. The breadth of most bricks is therefore limited to a 5in. maximum, for anything in excess of this is rather too wide for the average hand to span.

Another/
Another factor which affects the breadth of a brick is its relationship to the length for bonding purposes. It is essential for most bonding arrangements that the length be exactly twice the breadth, though, as already noted in the case of the 12in. brick, it is possible to build forms of Flemish bonding with a 3:1 ratio of length to breadth.

Bearing all these factors in mind, the module dimension of 4in. appears to be altogether suitable. This means of course that the actual breadth of the brick will be 4in., less the width of a cross-joint - about 3\(\frac{3}{4}\)in. or a little less.

Length, thickness and breadth of the modular brick have now all been considered separately and the brick (or bricks) designed by Mr. Osborne may be examined again, particularly with respect to the suggestion for a 12in. finished brick length. The volume of the 11\(\frac{1}{4}\)in. by 3\(\frac{1}{16}\) by 3\(\frac{1}{16}\)in. proposed brick is about 164 cu.in. and the volume of an ordinary brick, 8\(\frac{3}{8}\)in. by 4\(\frac{1}{4}\)in. by 2\(\frac{3}{4}\)in. is about 104 cu.in., if a frog is considered then the volume will probably be not more than 94 cu.in., maybe less than this according to the depth of the frog.

In putting forward this 12in. brick length it was stated by Mr. Thomas that perforating the brick would bring the weight/
weight of the 12in. brick down considerably so that it would be about the same as the ordinary brick. This is rather questionable for if the volume of the 12in. brick is 164 cu.in. and that of the ordinary brick 94 cu.in. then the perforations must must displace a volume of at least 70 cu.in. to make the volume (and consequently the weight) of the brick compare with that of the brick now in common use. Supposing \( \frac{3}{4} \)in. diameter perforations are employed, then each perforation would displace approximately 1.6 cu.in. of clay, so the number of perforations would have to be 44 to each brick. This, involving, say, 4 rows of eleven perforations would result in clay thicknesses between perforations of less than \( \frac{1}{8} \) in. and this, I imagine, would reduce the potential crushing strength of the brick considerably. Moreover, the breakages in transport and handling of a brick 12in. long would be common enough if the bricks were not perforated, so it seems that weight reduction by perforating such a long brick might well lead to a large percentage of waste in the form of halves and bats.

The dimensions I would propose for a modular brick follow closely the sizes of the middle brick in the range of three bricks designed by Mr. Osborne - 7\( \frac{11}{16} \) by 3\( \frac{11}{16} \) by 3\( \frac{11}{16} \) in. The only difference I have made is to alter Mr. Osborne's 7\( \frac{3}{8} \) in. length to 7\( \frac{11}{16} \) in. for I consider that a \( \frac{3}{8} \) in. joint allowance/
allowance is hardly enough to take account of all kinds of mortars and all types of bricklayers, not to mention the usual tolerances for bricks, even modular bricks, of plus or minus \( \frac{1}{16} \) in.

The gross volume of the brick proposed would be approximately 104 cu. in. and this is practically the same as the gross volume of the existing 8\( \frac{1}{4} \)in. by 4\( \frac{1}{2} \)in. by 2\( \frac{1}{4} \)in. brick. Perforations or frogs could be formed in the modular brick to reduce its weight to that of the ordinary frogged brick.

By adopting a modular brick that would build to 8\( \frac{1}{8} \)in. by 4in. by 4in. dimensions we should be following the American lead in this respect, but there is little point in trying to introduce a brick size peculiar to Britain merely to be different to everyone else. If a modular brick of this size was generally adopted in this country the savings in handling and in material should exceed the savings reported by the Americans, for I think it would be true to say that brickwork is used more widely in Britain for domestic building work than in America where softwood is so cheap and plentiful.

With the modular brick, conventional cavity walling could be built to an overall thickness of 10in. inclusive of wall finishings. This could be achieved by reducing the cavity to 1\( \frac{3}{16} \)in. but in order to satisfy the Model/
Model By-law principle of alternative performance standards it would be necessary to prove that these reduced wall thicknesses are equal in stability and all other respects to the conventional cavity wall which is usually 11 in. thick exclusive of finishings. Similarly it would be necessary to satisfy local authorities that the 8 in. solid walling and the 4 in. partition wall were of comparable strength to walling built from bricks of conventional sizes.

The saving in internal space owing to the reduced external wall thickness has been referred to in the part of these notes devoted to Walling, but it is perhaps worth while emphasising again that an additional strip, 1 lin. or more in width, of usable floor space all round the perimeter of the building, made available by a reduction in the wall thickness, can bring about a substantial economy by reducing the site area, roof coverage, etc., normally taken up by thicker external walling.

A modular facing brick would not have the aesthetic appeal of the narrower brick and there are probably many architects who would rebel against the inescapable monotony of the 4 in. courses. It might perhaps be possible to manufacture a modular facing brick, 4 in. deep, that was grooved horizontally or marked in some way that helped to reduce/
reduce this monotony of thick courses. This is simply heresy of course, so far as present-day standards of good facing brickwork are concerned, but for those that have no use for the undoubted economies inherent in modular brickwork there will always be the exclusive but expensive trickle of "specials" for those who are prepared to pay, whether they be purpose-made bricks or any other building component.

The Secretary of the Modular Society has suggested that a three inch partition brick might be a useful additional size to be added to the modular range of bricks, but I would not agree that this would be a good thing, for partitions are rarely built of brick now when so many alternative forms of material are available, many with finished surfaces ready for decoration. I do agree that half-bricks should be produced, for this has been urged for some time now in connection with the existing brick size. Mr. Thomas backs up his argument for a 3in. brick by describing how two wall thicknesses built of such bricks could be used to make up a 10in. cavity wall, but, as I have stated already, it should be possible to arrive at a 10in finished thickness with \( \frac{311}{16} \) in. bricks provided the plaster thicknesses are kept reasonably thin and the cavity is reduced to \( 1\frac{3}{4} \) in. or thereabouts. There is no reason why a cavity should measure a minimum of 2 in.; so long as the cavity is continuous it would not matter a lot if it was reduced to \( 1\frac{3}{4} \) in.
From the brief reference that has already been made to British research in the field of modular coordination it would appear that this work is being shared by three groups - the Modular Society, the Building Research Station and the British Standards Institution. The Modular Society, formed "to reduce building costs by promoting research, experiment, development and discussion concerning the use of the module in the design and construction of buildings and in the manufacture of building materials" has, among other things, adopted a 4 in. basic module and produced a Modular Catalogue listing building products which conform to that module.

Some considerable criticism has come from certain quarters of precipitate action by the Society in declaring for a 4 in. module and it has been suggested that more careful consideration should have been given to the final conclusions of the B.R.S. and the B.S.I. on a modular number pattern. I consider that the Modular Society is to be commended on taking positive action towards modular planning and construction. The Modular Catalogue is tangible evidence of a beginning which has been made towards the implementing of the aims and objects of the Society. It is not claimed that the Modular Catalogue brings complete solutions to the many and complex problems set up by tolerances, wall thicknesses, etc.,/
etc., but it does constitute something for manufacturers and architects to consider when they are planning production or buildings and, as the Catalogue grows in size and architects become more aware of it, then it is probable that the producers of non-modular building components will be persuaded into thinking in terms of the 4 in. module.

The investigations made by the B.R.S. and the B.S.I. appear to be directed towards the development of a pattern of preferred numbers which take into account the dimensions of all existing components and have a relationship to aesthetic design considerations and anthropometric measurements. This is no small task, particularly when it is considered that British Material Standards cover more than 18,000 products. Such a broad field of study involving so many variables obviously takes the investigation into the realm of the mathematician and one is entitled to wonder if, when a number pattern is evolved, architects and builders will be able to understand it, apart from the manufacturers.

It can be well understood that existing building components have at least 200 dimensions operating between 0 and 100 and that British manufacturers are bound to prefer a system of preferred numbers that will take account of these dimensions. The spokesmen of the B.R.S. and the B.S.I. have/
have stated broadly that they have to proceed slowly so as to take account of parallel research and to produce a system of modular coordination that will have a flexible application to the existing and future building pattern rather than to apply a rigid simplification of that pattern. This published intention to proceed slowly is understandable for it is difficult for a public institution to do any other, particularly in an important matter of research and formulation of policy such as this. However, the Modular Society, as a private body, has turned its freedom of action to good account by its decision to adopt the 4 in. module and its action in producing the Modular Catalogue.

The Catalogue was first issued in January 1955 and by October of that year it listed some 22 sheets dealing with partition blocks, structural roof panels, curtain walling in plastic, steel and aluminium, steel framework, building boards, suspended ceilings and precast concrete cladding slabs. Each of these sheets is devoted to a product of an industrial subscriber to the Modular Society and the simple requirement in each case is that the listed component shall be "available generally and have appropriate external dimensions in whole multiples of the basic module of 4 in measured to centres of joints or joining members."
From what has been written in these notes it is evident that the study of modular coordination has progressed since the Bailey Report on the Quicker Completion of House Interiors recommended a close study of modular planning as a means to reduce housing costs. But the rate of progress leaves much to be desired, while the British Standards Institution and the Building Research Station teams deliberate the continuously accelerating production of new building components goes on, and the confusion of dimensions is extended.

Even when the investigating bodies are agreed on a module or system of preferred numbers it will be left to the industry to accept or reject the proposals, for although some countries have made certain modular standards compulsory it is not likely to happen in this country. General acceptance of the benefits of modular coordination must be brought about by persuading architects that modular detailing in the drawing office can substantially reduce draughtsman/hours, also that materials related to a module can be assembled much more quickly within the discipline of a planning grid than non-modular materials and as a consequence of this the client pays less.

The/
The contractor need not be slow in appreciating the advantages of modular building as long as the problem of "tolerances" is squarely faced by him and the manufacturer. It will mean that bricks, window frames, door frames, precast concrete components, panels, etc., must all be produced with a low "plus" or "minus" tolerance figure and that the building craftsman must justify his calling by working to far more precise measurements than is customary in non-modular building. It has been said that precision building is necessarily slow building but I do not agree that this is necessarily so. Most building craftsmen will do their best to work to given measurements and will take it as a reflection on their ability if it can be shown that they have been responsible for an error of measurement.

But it is most essential that all prior measurements must be right, the bricklayer will not accept responsibility if, for example, he can relate walling errors at roof level to an initial mistake in the setting out of the building.

In modular house-building, it is probable that the setting out and the walling will be the two most likely operations in which errors will take place. On an undulating or uneven building site the problem of marking out the line of every wall and junction wall is a very real one and is a much more difficult operation than is generally appreciated by/
by the production engineer in the factory.

Nevertheless, there is no reason why buildings should not be set out and built to an overall room tolerance of \[ \pm \frac{1}{4} \text{in}. \] and I consider that the way to do this is to use templates of braced timber related to one main corner and a central datum post of some kind. The leading hand can be assigned to building and plumbing the main corner and each cell of the building checked from time to time against the appropriate template.

To end these notes on modular coordination it may be interesting to quote from the Transactions of the Modular Society for February 1955, in which an American architect says about modular coordination:— "We did architectural working drawings, and coordinated structural and mechanical work therefor, on a $3\frac{1}{2}$ million hospital in 105 man/weeks (at 40 hrs. each) for a 7% fee. Its one sheet of modular window details covered conditions that would require five sheets of non-modular drawings. On this job eight we had/construction bids, 6 of which bracketed a 5% spread."

This well-known architect went on to say:— "Shortly after World War II, one of our men studied up on the modular method a few evenings at home and lectured our men on a Saturday/
Saturday morning. We began making modular drawings the following Monday. Conversion was that simple. It has never been a complicated procedure for us, our structural engineers, or contractors who build our buildings. Our contractors have testified as to its layout advantages in the field. Their masonry foremen like Modular Coordination and say it makes money for them."
Angle Tooled, Angle Drove - Stone dressed so that the tool marks run diagonally across the face.

Astragals - Glazing bars.

Axed - Stone dressing applied to granite or other hard stone after the face has been reduced with a punch.

Back Boxing - Backlining of cased sash frame.

Balk, Baulk - Collar, of upper tie between rafters.

Band - Bond (Inbank and Outband).

Banisters - Balusters.

Bar - Ledge, e.f., a barred door is a ledded door.

Barge, Berge - A projecting stone drip at the base of a chimney stack to throw off water; a shaped timber drip housed to bottom rail of door; a board or plate to raking face of a gable; an apron (in lead or copper).

Base-Blocks - Plinth blocks (joinery).

Bases - Built up skirting with a plain board and separate moulding above.

Base-course - Plinth.

Bat - Metal cramp; lead wedge; iron cramp for fixing door frame; part of hinge built into brickwork or masonry; to caulk.

Bat-Bolts - Rag bolts.

Baton-Rod - Window bead, sash stop bead, staff bead.

Batten Door - Ledges door.

Baulk - See Balk.

Bellcast Pieces - Sprockets; also fillet at base of roughcast.

Belt-Course - String course; band course.

Beltling - Plugged bearers; hat and coat rails.

Bevel-Checked Joint - Bevel halving.

Berge - (See Barge).

Bilgate - Wood or breeze fixing slip for joinery built into the wall.

Biss - A concrete or timber stall division in byre or cowhouse.

Blaes, Blaze - Poorly bituminous sandstone, shale or fireclay in the coal measures.

Blocking-out - (Mason) Beasting (Joiner) rough grounds; fir battens.

Bond stones - Tie stones, stones periodically placed full thickness or more than half thickness of wall.

Boasted, droved - Stone dressing finished with a boaster, a 2½ in. to 3 in. wide chisel.

Boss-Head - Box staple for bolt of dead or rim lock.

Bossing - See Window Bossing.

Bottle nosing - Rounded nosing.

Bottled - Rounded.

Bottoming - Hardcore.

Bound - Framed, as in doors or roofs.

Branders - Counterbattens, grounds for plasterboard or laths.

Branding - Battening as last.

Breast - (of steps) Riser, (of windows) Portion of wall below sill.

Breast-Lining - Window back, panelling between window board and skirting.

Bridle - Trimmer.

Bridding joist - Trimming joist.

Brig, Briggs - Withes, divisions between flues.

Broached - Face of stone worked with a point to show diagonal or horizontal furrows.

Built-Dooks - Fixing pads; Hardwood plugs; Bilgatos (q.v.).

Built Steps - Built into, or on support walls.

Butt - Square or fitted end; heading joint (not used of hinges).

Bye-Wood Flushing - Planing down joints of boarded floors.

Camp - See Coom.

Cant - Tilt.

Cant (batted) - Stone laid with natural bed vortical and showing on face.

Causeway - Sett paving.

Channelling - Rebates on ashlar to form rustications or the like.

Check/
Check - Rebate.
Chimney Can - Chimney pot.
Chimney head - Portion of stack above roof.
Cladding, Cleating - Rough boarding, as scaffold boards or laggings.
Clean - Wrought (timber); also used for timber free from knots.
Cling - To shrink.
Clink - Welt.
Clour, Cloured - Hack or hammer dress stonework; to remove a projection in stonework.
Close-End - Stopped end of eaves gutter.
Club Skew - Springer; spur stone.
Goddings, Codings - Ped stones or templates.
Conductors - Rainwater pipes.
Coom, Coomb - Sloping soffit or ceiling.
Cope - (Masonry) (Coping (joinery), Top of pipe box or stair stringer; timber top to front edge of sink; cistern top or draining board (c.f. Haffit).
Copper Tacking - Copper nailing.
Corbic-Step - Crow step in stepped gable.
Corners - Quoins (see also Rybats).
Corner bead - Timber or metal bead forming arris of plastered walls (of Staff head).
Cormice - Projecting moulding over windows, doors, wall heads, etc.
Counter-Check - Rebated meeting rail of a sliding sash or folding door.
Coup - Rubbish tip; spoil heap.
Couple - Rafter.
Coursed rubble - Rough squared stone walling in courses to suit height of rybats or corners.
Crampets - Cramps, walls hooks, hold-fasts, or gutter brackets.
Cross-Tailed Hinge - Cross garnet or tee-hinge.
Debbed, Dabbled - Sparrow pecked with sharp point (masonry).
Dea fencing - Sound boarding; insulation; filling such as foam slag; originally ash filling between joists covered with plaster.
Die, Die wall - The dado, or cubical part of a pedestal, often with a half baluster worked on; baluster scattings in masonry worked on the plinth or handrail cappings; dwarf wall at side of steps.
Dooking - Plugging.
Dooks - Driven plugs (as distinct from Bilgates q.v.).
Doubling - Tilting fillet.
Drafts - Margins of stone tooled separately from the face.
Dressed - Finished face of stone; wrought (timber)
Drip Box - Cesspool in lead flat or gutter.
Drop - Outlet nozzle to eaves gutter.
Droving - Boasting, finishing the stone face with a 2½ in. chisel or boaster to a fine corrugated texture with parallel lines.
Dwang, Dwanging - Bridging, horringbone strutting, or nogging to floors or partitions.
Dyke - Dry rubble wall.
Edge-Hinge - Butt hinge.
Eko Piece - A length used to make up the required size, e.g. gulley riser, or extension piece.
Elbows - Vertical linings of windows at sides.
Exposed face - Pair face.
Facing - Moulding worked on exposed edge of timber, sometimes used for architrave.
Faucet End - Socketed end.
Fillets (tiling) - Battens (tiling).
Flank - Valley.
Founds - Foundations.
Freestone - Any fine grained stone, easily worked.
Gabbart-Scaffold - Scaffold built of squared timbers bolted together.
Giblet-Check - Scaffold built of squared timbers bolted together.
Gouging - Throating.
Gouffing - Underpinning.
Grip - Open drain in byre or cowhouse; any open drain.
Grunding = Battening or firring, plugged.
Haffet - Spandrel; triangular shelf bracket; dormer cheek.
Haffit - Frame for cover or lid; side of pipe box; cupboard sides (c.f. Cope).
Halflet - Eng of church pew.
Hand hole/
Polished - Stone face rubbed free from chisel or sawmarks by hand or machine.
Press - Cupboard (see also Wall Press).
Pugging - Dubbing out, rough rendering behind skirtings.
Punched, Punchioned - Studded (q.v.) stone face brought approximately flat with a punch or blunt pick.
Ragged-End - Roughened end.
Ragged - Housed; chased.
Raggled - End.
Raggled - End.
Raglin - Ceiling joist.
Rain-Conductor - Rain water down-pipe.
Rance - Shore or prop.
Rancing - Shoring.
Reind, Rind - Fillet.
Reprises - Stools or seats worked on sills for jambs or mullions.
Rest - Wall hold, bearing of a structural member on a wall; template or pad stone.
Rhone - Half round eaves gutter.
Ridge Pole - Ridge roll, wooden roll to take lead covering.
Rind - See Reind.
Rubbed jointing - Masonry joints rubbed with leather or indiarubber to remove marks and ensure close fit to irregular stones.
Rubble - Stones of irregular size and shape (see also Squared Rubble).
Run - Fall.
Rybags - Reveal Stones (c.f. Inban, Inga).
Saddle - Apex stone to gable; or a coping splayed both ways.
Saves, Savours, Saving Stones - Stones built over lintel to distribute load to jambs.
Sarking - Rough roof boarding, plain edge or rebated.
Seabbed, scappled - Rock faced stone roughly faced with pick or hammer.
Scale Steps - Fliers, steps with parallel nosings and equal going.
Scarocement - Plain horizontal set off or rebate in wall or foundations used as a shelf to carry ends of joists.
Schedule (of quantities) - Bill (of quantities).

Scoutions - See Scoutions.
Screw-nail - Wood screw
Scribbled - Hammer dressed beds or joints of masonry with marginal chisel drafts.
Scoutions, Scoucheons - Internal reveal; facing to reveal behind outband rybags (q.v.); return of a pier or pilaster; open finished end of a wall.
Shield - Escutcheon.
Shivers - Chippings; spalls; broken or crushed stone.
Shiver Bottoming - Harcore filling.
Shouldered - Torched.
Skew - The raking side of gable; stepped (flashing).
Skew Corbel, Club Skew - Springer; spur stone supporting gable coping.
Skew Rutts - Kneelers.
Skews - Stone slates used for swept valleys (see also Skew).
Slap, Slapped, Slapping - Cutting out to form an opening in an existing wall.
Slip Bolts - Barrel bolts
Slips - Glazing beads; cover fillets
Sludge cock - Draw-off cock.
Slump - Spot item without measurements.
Sneck - Lifting lever passed through a door to actuate the fall bar (e.g. Norfolk latch); small stones in squared random rubble, approximately 3 in. high.
Sneck-head - Latch catch.
Snecked, snecked rubble - Rubble walls in which the stones are roughly squared, but irregular size with small stones or snacks introduced to break the courses.
Snecked Harling - Roughcast showing the faces of occasional walling stones built proud.
Snecked Pointing - Flushing up the joints in walling leaving the faces of larger stones clear.
Sole - Still (usually applied to internal sill).
Solum - Area within containing walls of building after removal of top soil.
Spalls - Small pieces of broken stone
Sparred Shelving - Slatted shelving.
Spars - Rafters.
Spring Boards - Strings.