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 TWO VOLUME I

by

NORMAN C. SIDWELL, B.Sc. (Est. Man.), M.Sc.

"For the structure that we raise
Time is with materials filled."

"The Builders"—LONGFELLOW

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AN OUTLINE OF THE ECONOMIC STRUCTURE
OF THE BUILDING INDUSTRY

Attempts have been made from time to time to present an economic review of the building industry over the years but the lack of accurate statistical information has always placed serious limitations on such surveys. The Ministry of Works did not commence the collection of statistics until during the last war and this, of course, was initiated as a result of the war and the need for the strict control of materials.

There are a number of peculiar features in the building industry which need consideration in any economic study. The industry is probably the only producer of goods which cannot be taken from one place to another, therefore the production machine must follow the demand wherever it leads. Prefabrication at central points is carried on to a limited extent but the amount is negligible in comparison with the full production of the building industry and in many cases the prefabricated components are produced by the engineering industry.

The building industry is generally an outdoor industry and uses materials, methods and skills which require a reasonably fit and strong labour force. Consequently the labour is all male, though it is interesting to note that in Russia, women operatives are quite frequently employed.

Perhaps/
Perhaps the most peculiar feature of the industry is the wide diversity of firms, mostly small "one man" businesses, scattered throughout the country. It has been estimated that approximately 120,000 firms exist in the building and civil engineering industry of which only about 150 employ over 500 operatives. In 1930 the total number of firms was estimated to be 52,000 and of that total only 54 were employing over 500 operatives, so over 24 years the proportion of very large firms has increased from approximately .1% to .13%.(?)

Another peculiarity of the industry is the separation of the design and production functions. In practically all other industries, whether it be ship building, car manufacture, or foundry production, the designer is employed by the producer and functions as an integral part of the production machine - he is in intimate contact with all aspects of the work all the time. In the building industry we have the Gilbertian situation where the designer is separated from the producer and the two do not come together until the design is completed. Even then the link between them is not a strong one for the designer is all too often preoccupied with further designing and has possibly a multiplicity of other links with other producers. He gets a lot of experience from the various producers' applications of his designs but on the other/
other hand the producer is right down to the job and gains first hand knowledge of production method which would be invaluable to the designer if he had access to such knowledge. One of the greatest obstacles at the present time to reduced cost is perhaps this division of function, for while the designer can initiate new techniques he cannot, apart from an analysis of the tender, find out just how much money has been saved by the use of the new method because he is usually denied access to the absolute final costs which include the producer’s profit.

The building industry has an important place in the national economy. Census figures for the period 1881 to 1951 show that approximately 10% of the total occupied male population of this country has been employed in the building and civil engineering industry. In 1953 the value of work carried out by the industry amounted to a figure in the region of £1750,000,000, of which about two thirds was new work and the balance made up by repairs and maintenance. This represented between 6% and 7% of the gross national product.

The division of firms in the Scottish industry falls roughly under three classifications: first the large comprehensive contractor who handles large works ranging from housing schemes to civil engineering projects; then the smaller contractor who rarely ventures into the civil engineering field but is equipped to handle housing/
housing and commercial building on a medium scale; then finally the specialist firms which subcontract in individual trades or processes ranging over joiner, brickwork, plastering, plumbing, painting, slating and tiling, refrigeration, heating and ventilating, floor tiling, etc. The number of sub-contractors in Scotland is proportionately far greater than in England where the small comprehensive firm embracing all trades is much more usual. (A separate note on Scottish contracting methods is set out in greater detail in Vol. 1 of Part One.

Jobbing builders do not appear to be so common in Scotland as they are in England. The prejudice against any overlapping of the craft function is very strong in Scotland and a "one man" firm specialising in, say, brickwork will rarely take on plastering or slating, even in small amounts.

Additional to these three broad classifications of building firms are the large direct labour organisations which have developed so much during the post-war years. These organisations, largely controlled by local authorities or by such bodies as the Scottish Special Housing Association have taken an ever increasing part in the house-building side of the industry, but since 1954 it seems that the tempo of municipal house-building is steadying a little, and at the same time there are signs of the re-emergence of the speculative builder.
The growth of building firms is rather more restricted than the steady development of successful manufactories on fixed sites. When a building contractor tenders for a contract which is far removed from his headquarters he must face the fact that only a small number of his regular employees may be willing to leave their homes for an extended period. This means that the bulk of the labour for the new job must be engaged on the site and this poses a question of availability which is very hard to answer at the tendering stage.

The migratory character of the building operative has been formed by this habit of casual employment, sometimes near to or sometimes very far from home, either following the contractor wherever he leads or facing the alternative of a transfer to another contractor with work near at hand. These post-war years of full employment have persuaded many contractors to encourage more continuous employment by means of special transportation to and from the site and full wages paid for travelling time. Failing this inducement there is often the alternative of living accommodation on the site itself with canteen facilities and occasionally, quite well equipped married quarters. During my recent visit to a site some miles north of Ullapool I noticed that a fleet of luxuriously/
luxuriously equipped caravans, some twenty or so in number, had been towed on to the site for the use of workmen with families.

In spite of these innovations the building industry still relies to a large extent on the system of casual employment and and it seems true to say that the industry has suffered and is still suffering from the instability and lack of cohesion brought about by this constant movement of workmen. There can be no sense of intimate loyalty to any one employer under such transitory conditions, neither can beneficial personal contact be made and preserved. One Edinburgh contractor, whose firm is engaged on what is probably the largest and most important public building being constructed/at the present time has told me that he runs his firm on the basis of a family business, with no job at a greater distance than can be comfortably visited by him or his partners during the day. By the same rule he retains all his operatives and foremen who can count on continuous employment, as far as is possible, within reasonable travelling distance of Edinburgh.

The organisation of building firms during the nineteenth century was a comparatively easy task for any capable builder, for he had the means and the men, close to his/
his hand, to build practically all the work entailed in any job including the manufacture of all joinery components. The task of supervision did not worry him for he had his pony and trap in which he could drive out to the more remote building sites.

In these advanced times, buildings are larger and much of the work is the concern of specialist sub-contractors. The radius of operations has been extended far beyond the reach of that pony and trap or even of the high speed car. The personal contact between master and man is now a rarity and the old-time leading craftsman has now become the general foreman and between him and the contractor there is a man of rather higher education than the foreman, with a more extensive theoretical knowledge and the ability to organise a team of craftsmen, craft foremen and specialists. Far greater stress is now laid on organisation and management in all types of building firms, whether they be small family concerns or the large industrial undertakings involved in major projects at home and overseas. But the management function in the building industry is still regarded by the majority of builders as a new-fangled notion put forward by the engineering industry; this view is particularly strong in Scotland owing to a relatively smaller number of large firms coupled with a great many specialist trade firms.
The very large number of small firms in the building industry would seem to constitute the ideal competitive conditions of the economist, but there are many important factors which prevent the application of pure economic theory to the industry. One outstanding example of this was the monopolistic operation of the London Builders' Conference which was investigated in 1954 by the Monopolies Commission. The raw materials industries supplying the building industry are often influenced by cartels and monopolies.

Seasonal fluctuations in building activity are a further hindrance to the economic development and continuous operation of the industry. Then there are the fluctuations caused by the changes in national and individual demand for buildings. This last variation is frequently criticised by builders for it is generally felt that successive governments have used the production potential of the industry as a tap, to be turned on and off according to the financial limitations of the Exchequer at any particular time of crisis in the affairs of the State. Against these criticisms it must be admitted that in this complex running of the nation's employment and finances the Government of the day must be prepared to deal quickly with the booms and slumps which have such disastrous effects on the national economy. Nevertheless/
Nevertheless, since the contractor cannot be admitted to the confidence of any Government prior to decisions on the amount of national capital investment, it is the contractor himself who must bear the economic consequences of these unpredictable limitations on his individual output. And these limitations, so often unexpected, leave the contractor in a quandary, for he may be left with a large labour force which he has been at pains to recruit and keep together.

Unlike other entrepreneurs, the building contractors cannot, in slack times, continue to build up stocks against future demand. Instead they must either suspend or pay off surplus staff and run the risk of losing them entirely, or pay out wages to idle men. In this situation there is, of course, a potent argument for the increased use of prefabricated, standardised components, manufactured in the contractor's yard during these slack periods - and further reference will be made to this at a later stage when new techniques were examined. Meanwhile these brief notes on the economic structure of the building industry have, perhaps, served to show some of the problems which are peculiar to the industry and which stand in the way of this clamant and pressing need for the increased use of new methods and techniques, better management and other means of reducing cost in an industry which stands in peril of pricing itself out of existence.
Previous Enquiries into House-building Costs.

A number of enquiries concerning house-building costs have been made by various Committees and other official bodies. Perhaps the first in Scotland was that made by the Currie Committee, appointed in 1921 to "enquire and report as to the reasons for the high cost of building working-class dwellings in Scotland and to make recommendations as to any practicable measures for reducing the cost". The rise in cost which the Committee had to investigate was from about £300 before the 1914-18 War to £1000 after that war for an average three-apartment house.

Then there was the Report of the Barr Committee on Scottish Building Costs in 1939 which commented strongly on the excessively high cost of £410 for a three-apartment house and finally, in 1947, the Laidlaw Committee was appointed to "consider and keep under review the costs of house-building in Scotland, and to make recommendations."

The method of cost investigation adopted by the Laidlaw Committee was the analysis of costs of average houses completed in 1939 and comparable houses completed in late 1947. These cost analyses were difficult to make because so many variables prevented precise calculations. Tender prices since the war have hardly ever been on a firm basis and clauses providing for increases in prices of materials, time lost through/
through travelling or bad weather and many other such items make nonsense of any attempt to set down a reliable indication of the final cost of a house.

The Laidlaw Committee experienced difficulty in obtaining a sufficiently wide range of evidence on the final costs of completed post-war houses. This was due to the fact that the final settlement of a housing contract normally takes so long to effect after the actual completion of the houses. This has always been a sore point with contractors who sometimes have to wait several years before the final payment is made.

In analysing the costs of these pre-war and post-war houses the Committee broke down the costs of the pre-war houses into three elements—materials, labour and management—in the proportions 55:36:9 so that a house costing £480 was analysed as follows:—

<table>
<thead>
<tr>
<th>Item</th>
<th>Percentage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>55%</td>
<td>£264</td>
</tr>
<tr>
<td>Labour</td>
<td>36%</td>
<td>£173</td>
</tr>
<tr>
<td>Management</td>
<td>9%</td>
<td>£43</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td></td>
<td><strong>£480</strong></td>
</tr>
</tbody>
</table>

The element shown as Management covers oncose and profit. The item oncose includes supervision, office establishment, plant maintenance and depreciation, and selling expenses. From this it will be appreciated that the fixing of a reliable figure for oncose with reference to a particular contract presents no little difficulty. A manufacturer of a standardised component inside/
inside a factory is in a much more favourable position to estimate his overheads or oncosts than the average building contractor who has to base his estimates on such widely varying factors as expected turnover of business, overlapping contracts and even the vagaries of the weather.

In calculating the increased costs of 1947 housing the Laidlaw Committee put the rise in the cost of materials at 125%, the increased cost of wages at 52½% and the additional manhours caused by improved house sizes and standards accompanied by a marked fall in output accounted for a further 50% increase over 1939 costs. Taking into account items such as increased insurance, holidays with pay and guaranteed time the cost of the 1947 house came out at £1,280 against the £480 figure for the 1939 house.

This short description of the work of the Laidlaw Committee may not seem to bear directly upon the cost of new constructional methods because this particular investigation was limited to houses of traditional construction. However these references to substantial increases in manhours and materials, and to the difficulties in fixing figures for establishment charges and the like, will perhaps help to sketch in the background to this critical examination of the new constructional techniques. Indeed it will be very necessary to consider at length the cost of traditional house-building in order to establish a datum or basis for comparison.
During the years 1945, 1946 and 1947 a large-scale investigation of the cost of new methods of house-building was undertaken by the Ministry of Works. This research was closely linked with similar work carried on at that time by the Building Research Station and other Government agencies. The organisation set up by the Ministry for the collection of costing data, and the statistical methods employed for their analysis amounted to something which was completely new in cost analysis and the results obtained from the investigation make an important and valuable contribution to the scanty stock of knowledge on the cost of house building by new methods.

This Ministry of Works investigation covered, in the first instance, nine non-traditional sites and four traditional sites. On each site there was a group of at least 50 houses and each of the nine non-traditional housing groups employed a different method of construction varying from "no-fines" wall construction to precast concrete framing and panels.

The method adopted in all cases extended over three operations, site observation and recording, analysis of site records and a final statistical analysis. Considerable importance was rightly attached to the study of man-hours expended on the site and an observer system was developed which comprehensively covered all site operations. Observation had to be continuous so that unproductive time could be recorded, the observers were necessarily trained in the work and there had to be a lot of them.
them in order that each observer had no more than about twenty men to watch.

The observers recorded man-hours for all operations, summarised them daily and then, after reconciliation with the builder's books the summaries were sent to headquarters for analysis. The builders were, of course, under contract to the Ministry of Works and in many cases they were themselves the sponsors of the particular new form of house construction in their group. So there was no difficulty in gaining access to the builders own books - a facility not often enjoyed by an independent observer!

In all cases the observed man-hours were allocated against the appropriate building operation. These operations were set out on a Schedule and were eleven in number, ranging from foundations to finishings with the eleventh item under the heading of ancillaries. The total man-hours for each operation in a typical house in any group could then be stated. The figures for the foundations operation in, say, a poured concrete house would appear thus:–

\[
\begin{array}{c}
\text{Foundations} \\
\{ \text{Skilled - 2hrs.} \} \\
\{ \text{( } \text{) } \text{219 hrs. plus or} \}
\{ \text{ } \text{minus 11 hrs.} \}
\{ \text{( Unskilled-217 hrs)} \}
\end{array}
\]

Before arriving at these totals it was necessary to make adjustments for variations in houses on a particular site. A further adjustment had to be made to account for any initial slowness/
slowness of operatives on unfamiliar methods of construction. The advantage of having a number of schemes under observation is seen in the confidence limit of plus or minus 11 hours because this figure reflects the extent of the variation in the man-hour totals from an average of 219 hours extracted from a minimum of fifty houses on similar sites. This meant that the worst, or longest time taken on this particular operation would be eleven hours above the average of 219 hours and the best, or shortest time was 208 hours. The term "confidence limit" was given to these plus or minus figures and they gave a reasonably accurate measure of the variation between blocks on the same site. But it was realised after a while that the variations between unidentical sites might be greater and this proved to be so. Accordingly, analyses of these further variations were carefully made and it was found necessary to extend the range of the confidence interval in most cases.

Another factor which had to be considered at the outset was the initial slowness or what was described as the fumbling stage when new and unfamiliar operations took a long time to complete. An "improved time" adjustment had to be made so that the initial recordings of man-hours were removed, leaving figures more representative of a steady rhythm of output. Finally, an overall maximum of 90% confidence was applied to all results, since this was felt to be appropriate to most building operations.

From all these man-hour totals and material costs a reasonably accurate range of total prime costs was built up and compared. /
compared. In practically all cases the non-traditional methods showed an economy in man-hours over the traditional construction and in the best of the new methods the saving was as much as 40% for the part of the house to which they were applied.

In 1947-48 the Ministry of Works in collaboration with the Ministry of Health and various Local Authorities carried out further experimental house-building, using four new systems additional to the nine already mentioned. The cost analyses for these systems were very similar to those obtained previously and helped to reinforce the conclusions already drawn. One of the four schemes did however show a most striking reduction of man-hours owing to the operation of a bonus scheme. The total productive man-hours for the walling amounted to 190 ± 65 hrs. The walling consisted of storey-height precast hollow concrete panels with an external finish and internal lining of fibreboard applied in the factory, and of the other types of walling the one which compared most closely was of simple precast concrete posts with exterior and interior panels of foamed concrete bolted to the posts. The figure for this form of walling was 445 ± 190 hrs., there being no bonus scheme to reckon with here!

The Ministry Report on these additional experiments would appear not to have given sufficient weight to the effect that bonus schemes have on output for after noting that the man-hour totals are confused by the incidence of the bonus scheme/
scheme the Report goes on to say "Nevertheless, even if the effects of operating the bonus scheme had been to reduce the number of site man-hours by as much as 30%, the non-bonus man-hours would still be significantly less than for any other type."

This statement is surely open to criticism, for the 30% figure for increased output on bonus is decidedly low and the opinion here is that a figure of 60% would scarcely be an overstatement. The Girdwood Committee estimated the level of manhour output in 1947 at 45% above the 1939 level when there were no incentive schemes or mechanical aids other than the odd concrete mixer.

Between 1947 and 1949 the Girdwood Committee was considering its Second Report on the Cost of House-building, and in the Report it was noted that while there had been a slight improvement in output due to incentive schemes and design economies this improvement had been more than offset by increases in the price of materials, increases in the rate of wages and a growth in the average size of houses with the net result that the building cost of/
of the average 1949 house was about £79 more than the building cost of the 1947 house. \( (3) \) (142)

Following on the Second Report the Girdwood Committee issued a Third Report in 1952 in which it was stated that building cost of an average local authority traditional three-bedroom house completed in October 1951 was £1,450. This represented an increase of £129 over the cost of building a similar house in 1949. Perhaps the most significant expression of opinion in the Report was that, at long last, there were signs of a halt in the steady rise of tender prices.

The Bailey Report on the Quicker Completion of House Interiors was published in 1953 and in its opening chapter there were many references to building costs which were acknowledged to be three times as high as before the war. /
war. There was also the astonishing revelation that the number of manhours taken for the completion of a whole house can vary from 1,565 to 4,645 (this was taken from a recent Building Research Station Survey of the time taken to build houses of 850 to 1,000 sq. ft. area).

The main conclusions of the Bailey Report were that house building should be confined to a small number of interior plans, that there should be greater use of standardised products and dimensions, better organisation and a fuller use of new materials and methods of construction.

In a general way the Bailey Report provided a most informative schedule of costs and manhours in relation to new materials and techniques used in the construction of houses. In loadbearing partitions a 4½ in. brick wall plastered both sides was taken as a basis for comparison and the recorded cost savings for other forms of walling were - 4 in. clinker blocks 11%, timber studding and plasterboard cut on site 7% to 24% according to whether the plasterboard was plaster-skimmed or not. Completely prefabricated
prefabricated plasterboard panels reduced site manhours to one-seventh of the time taken to build and plaster a brick partition, but the actual cost saving after taking factory processes into account was only 10%.

In the non-loadbearing range of walling the yardstick used was a 3in. clinker or hollow clay block partition with two-coat plaster twice distempered on each side, and it was found that some forms of walling could be erected in a third of the manhours taken to build the basic walling. The final cost of the new types of walling fluctuated between a 25% increase and a 29% reduction on the basic cost. The linings of inner leaves of external walls produced very much the same variations in time and cost and it was interesting to note that it was the pressure-moulded gypsum panels, storey-height and in 2 ft. widths, that achieved the maximum saving in both partitions and linings.

From a comparison of floor finishes against $\frac{5}{8}$in. jointless pitchmastic it appeared that there were little or no savings in site manhours when tiles of any kind were used - thermoplastic resin, quarries or concrete tiles - and the cost was greater in each instance. In the construction of first floors it was shown that it was possible to save manhours by using prefabricated panels incorporating timber joists, $\frac{4}{8}$in. flooring and $\frac{3}{8}$in. plasterboard in two layers glued/
glued together as a ceiling, but the cost compared against an ordinary timber joisted floor with tongued and grooved flooring and skinned plasterboard ceiling was at least a third more.

Plumbing and water heating systems were also considered in the Bailey Report and some interesting comparisons made against a conventional system consisting of copper pipework, back-boiler heating unit, cast iron two-pipe soil and waste disposal - all applied to a bathroom and W.C. on the first floor of a two-storey house. Partially prefabricated plumbing systems were compared against the basic system and they ranged from partly assembled pipe runs with pre-cut and pre-bent piping to a one-pipe soil and waste systems prefabricated in copper with asbestos cement vent pipe and a combined hot and cold water storage unit.

These partially prefabricated systems naturally showed a substantial saving in site manhours - more than 50% in one case - but the final cost was higher than the cost of the basic system. The increase was not great; for the three partially prefabricated systems the cost was 5% more for a 42½ saving in site manhours, 15% increase for a 50% saving and the system with the least amount of prefabrication showed an increase of 8% for 32½ saving.
Finally, in this comparison of new methods against conventional construction the Bailey Report reviewed various methods of electrical installations and compared site labour totals and final costs with those of conventional systems of wiring (with supply intake unit, main switch unit, circuit fuse unit and skirting plugs. Wall runs and switch drops only in light gauge, open joint, lug grip conduit - tough rubber sheathed, V.R.I. cable throughout).

Here it was encouraging to note that a pre-assembled cable wiring "harness" in tough rubber sheathed/combining conduit in wall runs only, came out cheaper than the conventional method and achieved a saving of more than 30% of the manhours taken on site to install the conventional system. The ring main circuits came out cheaper still, though the site manhours were only slightly reduced.

These figures taken from the Bailey Report show a general tendency for new techniques of construction, particularly those techniques based on pre-assembling and prefabrication, to effect a substantial reduction in actual time spent on the building site, and although there appeared to be a consequent increase in the final cost of the new methods the amount of additional cost was never very large/
large and it is very likely that the increased costs were due to factory processes that might well be reduced if a sufficient volume of work flowed regularly through the workshops. Another factor that must be taken into consideration is the financial advantage consequent upon the shortening of the overall time for completion of the building. If two gangs of workers can be employed at the same time, one in the factory and one on the site, then it is obvious that the building will be completed in a shorter period than if all these workers were following each other on the site.

It follows then, that if the total time from commencement to completion can be cut down considerably, there must be a cash saving in interest payable on capital equipment and materials tied up on the site. This point has been laboured before in this thesis, and it is a point that should be emphasised, for too few contractors realise how essential it is to take full account of this cost consuming and profit paring item in building economics.

The figures that have been quoted here are taken from a Report that was completed in 1953. Since then the index of hourly earnings in the building industry has risen from 100 in 1952 to 114 in 1955 and materials have risen from 100 to 103 in the same period. Clearly, the total of manhours is more important now in any assessment of cost, but the difficulty here is to establish whether factory costs have increased proportionately with building labour costs.
Following a pilot survey of productivity in house-building between January 1948 and March 1949 the Building Research Station embarked on a second survey covering the period March 1949 to the end of 1950. The main objective was to determine the causes of high and low productivity in the post-war house-building industry and the general method was to compare total manhours per house together with labour expenditure on the various trades.

Sample surveys were made of 177 completed housing contracts. Only traditional houses were considered and some considerable care was taken to select contracts of comparable size and generally representative of the overall pattern of house-building. The scope of the enquiry was limited to England and Wales and the London area was excluded.

In analysing survey data a number of factors had to be included giving consideration to the size and form of construction of the houses, the extent of sub-contracting, incentives, contractor's experience, etc. and after giving due weight to these considerations a surprising variation of labour expenditure was revealed in the final analysis. For example it was found that for all trades, the upper limit of labour expenditure was about twice the lower limit.

The methods employed in collecting data and analysing it may prove useful when costs of new constructional techniques in Scotland are examined. It is unfortunate that this survey of traditional house-building productivity did not extend to Scotland however, for it would have provided first class comparative data.
Early in 1951 the Ministry of Education published (27) a Building Bulletin on Cost Study with reference to new schools. A new method of cost analysis was described and in Appendix 1 the effect of plan shape on cost was discussed. The analysis of cost on a cubic foot basis was regarded as unreliable because variations in ceiling heights between buildings of identical area gave completely different totals in terms of volume.

A basis of cost per square foot of floor area was recommended and in apportioning the cost of the various parts of the complete building over the superficial area a novel series of "elements" was introduced. These elements, some thirty in number, represented all the component parts and processes in a building which form part of the overall cost. They ranged from "preliminaries and insurance" to "playgrounds and paved areas" and distinguished between "plumbing(external)", "plumbing (internal)" and "plumbing (sanitary fittings). The main idea of these elements was, of course, to get away from the complicated and detailed descriptions found in bills of quantities and, instead, to express the parts of the building in functional terms.

This breakdown of cost is realistic and quite obviously is a convenience to an architect in comparing unit, or element costs with similar elements in other schools. For example, if the ironmongery in School A cost 4.9 pence per square foot/
foot, then the ironmongery in School B should not vary unduly from this figure. Again, the element costs are of great value in cost planning a new building. The overall cost of a new school is quickly arrived at by multiplying the number of school places into the allowable or target cost per place. Then the cost of all elements can be worked out proportionately or by a process of elimination, starting with say, external walls and facings, the frame and the roof. Element costs for completed schools represent a reliable guide and extra costs on some elements can be offset by savings on others.

Following the Ministry of Education Bulletin on Cost Study a number of local authority architects analysed costs on the lines suggested. One outstanding analysis was made by the County Architect to West Riding of a secondary modern school near Barnsley. The component classification (element breakdown) differed considerably from the Bulletin classification in that fewer elements were listed and this meant a certain amount of grouping. The six main categories of building components were defined as structure, cladding, partitions, finishes, equipment and services. To these six elements a seventh was added, covering contract charges such as preliminary costs and insurance.

The seven main elements in this West Riding analysis were in turn broken down into some 35 sub-elements. Under "cladding" for example, was grouped damp-proof membranes, external/
external frames (doors and windows included under this), external panels, external glazing, roof cladding, roof lights.

This classification under a reduced number of main elements is probably an improvement on the Ministry of Education arrangement, for it is much easier to form a quick comparison of costs with only seven groupings to consider. The whole question of component classification is one which must be separately posed for each type of building and it will be interesting at a later stage in this investigation to work out a suitable classification for a two storey house and a block of flats.

In both the Ministry of Education Bulletin analysis and the West Riding research the method was to analyse tender costs and final account costs. The collection of site costs requires the employment of site observers and the active cooperation of builders and operatives, and this can be very costly and difficult. In any case the Ministry is mainly concerned with the manner in which local authorities spend their money and a study of tender prices is appropriate.

The analysis of total cost per square foot of floor area by elements based on tender prices is probably the quickest way of getting an answer and analysis of final account and site costs at a later date will always act as a check on the builders' estimates.
Towards the end of 1954 the British Productivity Council published a Review of Productivity in the Building Industry. This review, though heralded as a panacea for the ills of the industry merely comprised a meticulous summarisation of the many reports and statistics which have been published during the post-war years. Reference was made to the substantial increases in costs, particularly with regard to the increased cost of raw materials and labour wages which were estimated to have risen two-and-a-half times since 1939. Interesting tables and charts were included showing the increases year by year. Mention was made also of the increase in the size of clerical staffs which had been largely brought about by licensing, the need for compiling statistical returns for Governments, preparation of costing records and clerical work in connection with incentive schemes.

The Review made some mention of the effect of mechanical aids, new materials and methods on the cost of house-building and particular reference was made to the recent developments in Scotland of crosswall construction for/
for terraced houses and flats, also the extensive use of "no fines" concrete walling and the development of precast concrete hollow block walls with imitation stone face.

On the subject of pre-planning the Review was rather optimistic in stating that "pre-planning is being effected to a far greater extent than in the early post-war years". Apparently this assertion was based on the use of pre-planning on the sites administered by Scottish Industrial Estates Ltd. and on the construction of the Esso refinery at Fawley. Altogether the British Productivity Council's publication was a disappointment to many who read it and had hoped that it would contain some useful help to the building industry. As one critic said - "If the Productivity Council wants to aid our industry let it get down to brass tacks and tell us just what to do to increase productivity and tell it to us in a language and form which small builders working long hours will find worthwhile to study and put into practice".
This survey of previous enquiries into the cost of building has revealed a great deal of unanimity on a number of points. For example, in most of the enquiries considerable difficulty was experienced in obtaining really constant results from cost analyses owing to the incidence of so many varying factors in the house-building industry. Again, all reports were unanimous in stating that the cost of house-building had risen during the post-war years to a figure three times the 1939 costs.

The experimental work carried out by the Ministry of Works and the productivity surveys made by the Building Research Station made a useful contribution to the rather scanty stock of data on costs. Most certainly, the M.O.W.'s comprehensive and thorough investigation of site costs on non-traditional house-building emphasised the special problems which arise when new constructional methods, applied by operatives skilled only in traditional methods, have to be observed, measured and costed and then compared against the cost of building traditional houses.

The Ministry of Education Bulletin on Cost Study (with reference to new schools) was a noteworthy development of a new method of cost analysis, particularly because

the/
the method evolved is capable of being applied to buildings other than schools and the analyses obtained are in a most convenient form for cost-planning similar buildings.

Most enquiries into costs and investigations of productivity agree that the principle of prefabrication in house-building can be carried further provided that the costs of factory production can be brought down to a reasonable level. The general opinion appears to be that the present advantages of the application of the technique of factory production to non-traditional construction lie in the speedier erection of houses, thus relieving the demand for skilled building labour and materials. Both the Girdwood and the Laidlaw Committees deprecated the fact that special subsidies had been made available, in addition to normal subsidies, to most of the non-traditional houses built during the first post-war years. The special subsidies were paid under Special Grant in respect of houses which had proved to be more costly than comparable traditional houses.

Despite these opinions it is considered that definite conclusions about the cost of non-traditional houses cannot be drawn from the evidence provided by these early experiments. Cost analyses of more recent house-construction are required together with more accurate information about the costs of the factory-made components and elements which characterise new constructional methods.
Cost Analyses by an Elemental method.

The purpose of a cost analysis of a building is to make available the cost data from buildings already planned or built, and to apply this data at the design stage of other buildings so that costs may be reduced and provision made for a proper economic balance between each constituent element of the building. Architects are becoming far more conscious nowadays of the need for accurate information about the cost of this or that method of construction or of certain types of fittings or combinations of new and old materials, and it is essential that this information should be available at the design stage.

Analyses based on costs per foot cube are necessarily very approximate and the rigid division of bills of quantity according to trades has little relationship to the functions of a building. The walls of a large modern building generally serve as a cladding only to a structural frame, and the architect regards this cladding according to the function it performs - appearance, weather resistance, thermal insulation, etc. It matters not whether the cladding is of hollow plastic panels containing large glazed areas or eleven inch brick cavity walling with small glazed areas; the architect wants to be satisfied that the cladding will measure up to the/
the requirements for the cladding of that particular
building and, moreover, he wants to know quickly, what the
cost of the cladding he chooses is likely to be. The architect
can, of course, ask a quantity surveyor to give him an
estimate of the cost of a particular cladding wall. But in the
absence of cost analyses of previous work the quantity surveyor
may take a little time about this and may require some rough
details of window openings, finishings, frames, etc.

What is needed then is a method of apportioning the
cost of a building in order of function and not by trades and
*this has been recognised by the Ministry of Education which
has carried out considerable research in the development of
a method of elemental cost analysis applied to school buildings.
In this method the entire construction of a school is broken
down into a series of elements—walls, frame, roof, cladding,
finishings, etc.—and the cost of each element is abstracted
from the priced bill and expressed in terms of superficial
area of building. For example, the cost of a school having
a superficial floor area of 72,660 was £227,445 and this
works out at £3.12 per square foot. The cost analysis showing
how every penny of this £3.12 was applied to each of the
functional elements is most revealing—the internal
partitions for instance cost 8/5d per unit super foot and the
cloakroom fittings/

* A more general reference has already been made to this.
fittings cost 1\£ per square foot.

These figures which are brought out in the cost analysis serve as a "target" cost for the architect to use as he considers each element within a design which is nearly always subject to an overall cost limitation. It seems quite obvious then that these analyses should be available at the design stage and should cover a very wide range of newly completed building work.

There are many difficulties which stand in the way of the preparation of such a comprehensive range of cost analyses and there are certain limitations on the usefulness of them. The difficulties as I see them are as follows:-

1. The trades sub-divisions of an ordinary bill of quantities are unsuited to cost analysis by elements. It takes a long time to abstract items of cost from the bill and list them under the appropriate element. In Hertfordshire the County Architect has had prepared a special bill of quantities, sub-divided by elements instead of trades, and this bill is sent to the contractors for pricing in this new form.

Where the contractor combines all trades within his organisation there should be little difficulty in pricing each item as it appears in the bill, whether it be steel framing erected in one paragraph followed by the painting of that framing in the following paragraph or carpenter work on boxes for holding down bolts, all appearing on the same page.
page. But serious difficulty arises when, as is generally the case in Scotland, the contractors invited to tender are mostly single trades contractors. Quantity surveyors in Scotland make special provision for their bills (or schedules) of quantities to be sectionalised in such a way that a copy of the appropriate section containing say all the brickwork items can be sent direct to a single trades contractor for individual pricing as a separate contract or sub-contract, and it would scarcely be possible for a single trades contractor to pick out and price all the relevant items in an elemental bill.

It might be possible to distinguish the particular trade items in some way so that they could readily be picked out by each contractor. The suggestion has been made that coloured pages might be used denoting the particular trade, but this is hardly practicable when an elemental bill mentions three or four trades on one page. A better plan might be to fix coloured tabs against the paragraphs as they refer to the trade represented by that colour.

2. A further difficulty is that different people have different opinions about the elemental breakdown of a particular building. The West Riding County Architect has, for example, adopted rather a different pattern of elements than that used by the Ministry of Education and other county architects.
architects. Such differences in method and elemental pattern are unavoidable when one is dealing with different types of buildings, but it ought to be possible to arrive at a standard breakdown for particular buildings (schools in this instance), otherwise the essential interchangeability of analyses between local authority architects will not be possible.

3. The analyses may quickly become out of date, according to changes in the cost of materials or labour.

4. It is not easy to obtain the consent of all parties to the use of price rates contained in the bill. This information is after all, copyright which is vested in the builder and he may be unwilling to allow the disclosure of his prices, even in the form of elemental costs. I have already experienced considerable difficulty in obtaining priced bills for analysis owing to this very same reason.

Notwithstanding these difficulties, the elemental method of cost analysis deserves a reasonable trial so that the advantages of the system may be set against these shortcomings. Already there have been a few contracts let on elemental bills and the future may see the creation of cost analysis reference libraries containing a wide range of analyses of building costs, representative of various regions throughout the country.
Summary of the Critical Examination - New Constructional Techniques (Vol. 2 in Part One) with special reference to productivity and cost.
SITE WORKS.

Foundations. There is no problem of shrinkable clay in Scotland and for that reason the short bored bearing pile is not likely to be used to a great extent there.

The mechanical excavation of foundation trenches can be profitable on housing sites where the houses are one, two or three storey types, semi-detached or terraced and where the minimum number of houses on the site is equivalent to twenty pairs. Increased productivity and consequent cost savings can be achieved only if the plan form is suited to the limited manoeuvrability of the machine and if there is a high standard of site organisation ensuring continuous employment of the machine while on the site. Special trenchers are economic only when a contractor has a clear run of work for such specialised machines extending beyond a minimum of two years. The small, multi-purpose adapted tractors, e.g. "Dinkum Diggers" are a far better proposition for the average sized contractor, and this has been confirmed by the experience of a number of the larger house-building firms in S.E. Scotland.

In the concreting of foundation trenches the synchronisation of the immediate discharge of the contents of/
of the mixer drum and the removal of the concrete via barrows, delivery booms or rails has for a long time presented a problem in concreting operations. Most contractors mix their concrete mechanically but too many try to transport the output of their machines by old-fashioned hand barrows and thereby neutralise the economic advantage of mechanical mixing.

It is essential that the transporting medium should have at least a 7 cu.ft. capacity in order to take the entire discharge from a 10/7 mixer and this investigation has indicated that the tracked form of mechanical barrow is efficient, the most transporter of concrete over soft and undulating ground.

The placing of concrete by pumping is hardly suitable for normal house foundations on an open site, and where the pump and supply mixer are not likely to be needed for other purposes such as floor construction in multi-storey flats. At the same time, pumped concrete has attractive possibilities with its direct and positive delivery coupled with flexibility at the point of delivery. The pneumatic method described and summarised under Floors may, in the future, be adapted to a mobile mixing plant developed for use on the more open housing estate site as opposed to the present adaption to high buildings on congested sites.
A new process of forming foundations for houses by using stabilised soil has been tried out in Stourport, Worcestershire, and substantial cost savings are claimed for it. In this process, which replaces concrete with a reconstituted soil mixed with cement or calcium chloride, a well-drained sandy soil is found to be generally suitable and special mechanical equipment is used.

In the Worcestershire experiment roads were laid in stabilised soil and then arrangements were made for an exact comparison of the costs of experimental stabilised soil foundations and those of traditional concrete construction, taking all aspects into consideration—manhours, wages, machinery costs, materials and oncosts. Three blocks of houses, two blocks with 38 houses and the third block containing 34 houses were chosen for the experiment. The third block was used for a trial run to discover the teething troubles and then the other two blocks were costed—one being constructed on concrete foundations and the other on stabilised soil.

This experiment showed that stabilised soil foundations cost £73.16.0 per dwelling against £77.14.9 for the concrete foundations, i.e. a saving of £500.17.6 was spent on experimental work determining the suitability of the soil and the best method of constructing the foundations.
An analysis of costs obtained from a B.R.S. survey of 72 different blocks of multi-storey flats up and down the country has shown that the substructure is responsible on average for 8% of the total price for each complete block, whatever the number of storeys in a range of from six to eleven storeys. On the elemental basis of spreading the cost of the substructure over the entire floor area one would imagine that the cost of the substructure would diminish as the height of the building increased. But it has been shown that the expected reduction is cancelled out by the increased cost of providing deeper or more complex foundations for the taller and heavier buildings. The graph on the next page gives a clear indication of rising cost as the height of the building progresses.

In the 72 blocks included in the B.R.S. survey the foundations ranged from strips to piles, column bases and rafts in all types of soil conditions. Most of the piled foundations were above the average of 3/0d. per sq.ft gross and it was quite obvious from the analysis that the strip foundations played a large part in keeping the average cost down to that figure.

It is interesting to compare the results of the B.R.S. survey of 72 blocks containing 865 maisonettes (23%) against/
Graph showing comparative costs of various kinds of foundations for a typical block of flats.

(Reproduced from a paper on Architectural Economics given by Professor J.L. Martin at R.I.B.A. Conference 1956)
against a cost analysis of four 11 storey blocks containing 75 maisonettes in each block. This analysis was included in Dr. Martin's paper at the 1956 R.I.B.A. Conference, and it indicated that the cost of the substructure amounted to 11.18% of the total - more than 3% above the average for the 72 blocks of flats. On the other hand, analyses of two point blocks built by the L.C.C. early in 1955 show that the substructure cost only 4% and 5.5% for each point block respectively.

Although comparisons between cost analyses can be very misleading, the discrepancies here are not great and could no doubt be easily explained. The important thing is that there should be as many of these analyses as possible, covering all types and conditions of site and foundations so that informative charts such as that on the previous page may be built up for particular areas. In this respect the B.R.S. survey of the 72 blocks of multi-storey flats over a wide area in Britain has produced a stock of most useful information on different types of foundations.

But if all the facts and figures on foundations alone could be related to the actual buildings, and particularly to the actual areas - London, Provinces, Scotland - from whence they came, then they would be of added value to local authority and private architects in those areas.
Drainage

It has been clearly shown that there is scope for economy in ordinary house drainage in Scotland. Existing methods have not changed during the past twenty years and local authorities are loathe to permit any departure from a system that has continued for so long without any major difficulties arising.

The number of individual connections between house drains and sewer should be restricted to a bare minimum in the interests of efficiency and economy. The number of manholes in many layouts could also be reduced without prejudice to efficiency, and bearing in mind how difficult and expensive it is to prevent subsoil water penetrating through manhole walling it is evident that most manholes could be constructed more economically by reducing wall thicknesses and foundation sizes. Outside offsets to concrete foundations to underground manholes constitute an obvious wastage of manhours and materials on needless excavation and concrete.

The high cost of maintenance consequent upon frequent blockages from hardened cement jointing in bends, branches and other inaccessible fittings could be reduced substantially/
substantially if the Code of Practice tests for obstruction were properly applied to all new drains. It seems utter nonsense that any local authority should not carry out a test so simple as rolling a wooden ball through every branch, bend and length of drain in every new house. The cost of the equipment - turned hardwood balls, a half inch or so less in diameter than the drain to be tested - is negligible, yet very few, if any, local authorities apply this test. The same local authorities however, carry out exhaustive tests with smoke, air and water, to detect the presence of a mere pinhole in the joints of drains that lie several feet under the ground. Such minor defects are seldom likely to cause the expensive maintenance that so often results from drain blockages.

The suitability of the 4 in. diameter pipe for the drainage of several houses has been pressed by the Committee responsible for the Code of Practice for Drainage and if the description "several houses" is interpreted liberally, say up to eight or ten houses, then there is a real opportunity in Scotland for a significant saving in labour and materials on most housing schemes. At the moment, it is usual to drain one or perhaps two houses on a/
a 4 in. diameter drain but when more than two houses, four at most, drain into a single pipe, then the diameter is stepped up to 5 in. or 6 in.

Reference has been made to intercepting traps and to the £100,000 annually which is spent by local authorities on the maintenance of drains, particularly in clearing blockages that arise through the provision of these traps between house drain and sewer. Local authorities in Scotland are generally in favour of the trap and it is unlikely that experiments and statements by the Building Research Station will have any influence on the attitude of the local authorities in this respect.

The comparison of costs of stoneware and pitch-fibre drainpipes set out in Vol. 2 of Part One indicated that the cost of a drainage system carried out in pitch-fibre pipes was less than for a similar layout in stoneware. But it must be remembered that the margin of economy is not very significant when the comparison is made against fireclay ware pipes - the quality of pipe that is usually specified in Scottish house-drainage work.

There is a wide variation in the standard of drainage as accepted by the various local authorities in Scotland.
Scotland. In a large city or burgh in Scotland a house drainage scheme may cost £60 or more per house, yet in an adjoining authority's area the cost per house might be £30 or less.

There can be no justification for such a variation. Either the one or the other is right, either one scheme is extravagant or the other is inadequate. If a scheme is inadequate then such circumstances may lead to high maintenance costs at a later date. Local authorities should clearly get together and put an end to this intolerable situation where an architect or contractor has to adapt himself to such wide variations in drainage or construction. The means for this adoption of a standard building code is ready to hand, the Dept. of Health's Model By-laws lay down a standard, reasonable set of regulations for all classes of building work, and it is to be hoped that the larger Scottish authorities will soon come in with those smaller authorities who have adopted by-laws based on the Model. At the same time it is hoped that these authorities will relax the existing requirements for underground traps - the "low-back syphon" and the two-piece Buchan intercepting trap - both traps constitute an impediment to free drainage and a needless addition to housing costs.
Scaffolding. Scottish methods of scaffolding, particularly in connection with housing work, are very different to the methods commonly adopted in England, for it has been shown that Scottish craftsmen are accustomed to working from internal scaffolding or from light forms of timber brackets placed against the face of the wall. The habit of working overhand from the internal scaffold is deeply ingrained in the Scottish bricklayer, and although it cannot be possible to achieve a high standard of craftsmanship in facing work under such conditions it is difficult indeed to persuade the builders to appreciate this. Quite recently on large-scale extensions to Portobello Power Station, Edinburgh, the clerk of works insisted that the brick facing work should be built from an external scaffold but the bricklayers complained that they could not work well under these unfamiliar conditions and asked to be allowed to work overhand!

Under the existing single-trade contracting system in Scotland there is little prospect of a change to external forms of scaffolding unless H.M.Inspectors take a firmer line in enforcing the provisions of the Building Safety and Welfare Regulations. If such enforcement/
enforcement should be made, it is certain that many of the smaller contractors would find it necessary to revise their schedule rates to meet the increased cost of providing adequate scaffolding, whether they hired or purchased the equipment or whether they arranged with the first trade contractor on the site to use his scaffolding for an agreed payment (indirect hire).

The use of the actual floor of the building as a scaffold is undoubtedly a cost-saving technique so long as those that are forced to work from the face of the building are allowed to do so on cheap and makeshift forms of scaffolding already described and so long as the Scottish builders are content to produce facing brickwork of a quality that would be unacceptable in England.

It has been useful and instructive to compare scaffolding methods in Scotland with the methods followed in other countries, particularly in Italy where much of the constructional work - the reinforced concrete framing, the panel walls of hollow clay blocks, etc., is carried out from the inside of the building, yet, at the same time, proper provision is made in the form of cantilevered putlogs to carry a comprehensive external system of scaffolding from which the outer finishings and furnishings can be applied or fixed.
In this costly era of expensive manpower the time spent on scaffolding may build up a cost item which is more than the cost of the particular job. This is true on many examples of repair work and in high and exposed places on new buildings, and is yet another point to be taken into consideration when comparing the cost of a flat or low-pitch roof with a traditional 40 degree pitched roof involving high gables and chimney stacks that will one day require repair.

Whatever the future policy is concerning high and inaccessible parts of buildings in the houses yet to be built, there are many thousands of existing houses that will need high repairs at one time or another, and it is to be hoped that something a little less costly than traditional scaffolding will soon be available for this ever increasing volume of repair work. Probably the most suitable device is the hydraulic platform, extending from a specially equipped lorry in any direction - either up, down, round or sideways. This has been developed by several firms specialising in this kind of thing and it is interesting to note that such platforms are being used by Messrs. Elvins & Sons of Birninghom on new building work. The savings achieved have been as high as 86% in connection with the handling of asbestos roofing sheets where it took only 40 minutes to place 85 sheets instead of a normal 24 manhours.
WALLS

Bricks or Blocks?

The technique of building load-bearing walls with bricks of conventional size and shape has been employed in the industry for so long now that it has come to be a standard process or yardstick against which all other forms of loadbearing walling are compared. Some mention has been made of the recent efforts of the Fletton brickmakers to produce a "deep frog" brick in the interests of increased productivity but since the note was written concerning this new venture the opposition from certain sections of the industry has been so strong that the manufacturers have revised their design in deference to this opposition. This puts us back where we were to the position as it has been for the past 25 years - the only difference in the "yardstick" is that the bricklayer in this post-war era - though equipped with mechanical service, plasticisers, frost resisting agents, etc., does not seem to be able or willing, in the absence of financial incentives, to build with a speed and quality compared with the pre-war bricklayer.

A discussion of the merits or otherwise of incentive schemes in the building industry is outside the scope/
scope of this thesis but it may be stated quickly and with certainty that, so far as conventional brickwork is concerned, the increase in productivity where incentive schemes are operated is truly remarkable. It has been shown that bricklayers may double or even treble their rate of work in response to the right amount of financial inducement. The capacity for such increases in production infers that the normal tempo of working (without incentives) is by no means what it should be and it would appear that this can only be due to full employment in the industry.

Full scale experiments carried out by the Building Research Station and exhaustive research in Germany and other countries have shown that the use of blocks instead of bricks can achieve substantial savings in manhours and in final costs. Yet the industry in this country lags far behind other European countries in the use of concrete or clay blocks for walling purposes. There is indeed a very gradual change taking place in the preference of Scottish builders for clinker blocks for internal partitions in place of brick partition walls but this has gone on for a long time without showing any marked sign of extending to block built external walls.

The reasons for this adherence to conventional methods/
methods of building in brick in the face of all the evidence that block walling may be built faster for less manhours may be summarised as follows:

(i) Trade unions and craft associations do not favour the subordination of the skills and processes necessary in brickwork to the simpler technique of blocklaying, and in any case they will not permit semi-skilled operatives (not in possession of a bricklayer's union card) to lay the blocks. The bricklayers themselves prefer to do the work they have been trained to do rather than learn a new technique which involves the handling of larger and heavier units.

(ii) Local authorities are slow to accept new and unfamiliar materials and techniques. Even when new model by-laws are framed to permit the use of new methods of building there is great difficulty in persuading the local authorities to adopt the new by-laws! The latest model by-laws issued to all Scottish counties and burghs by the Department of Health in 1953 have not so far been adopted by a single large Scottish local authority.

(iii) Brick manufacturers in the United Kingdom can exert a powerful influence in restraint of would-be block manufacturers. There are many small brickmaking concerns/
concerns up and down the country and there is of course the National Coal Board which is responsible for the production in millions of bricks in Scotland as well as/England. But in terms of actual production the London Brick Company is probably the most powerful manufacturing combine in the British Isles and is in a position to dictate policy to an extent which is not always obvious to most ordinary people.

During a recent visit to the Building Research Station at Watford I was most interested to see the experimental work that had been carried out on the extrusion of hollow clay blocks and there seemed little doubt that the B.R.S. is most enthusiastic about the economic possibilities for block-built walling. However, when I asked why it was that hollow clay block walling was not universally adopted in preference to brick the answer was that the powerful brick-manufacturing combines saw to it that hollow clay block manufacture should not be allowed to supersede and subordinate the existing brick industry. I was told that the brick combine adopted the simple strategy of maintaining its own plant for manufacturing hollow clay blocks. This plant was kept in production at all times and when any attempt was made by an outsider to produce blocks for economic/
economic building the larger brick combine stepped up its production of clay blocks and undersold the outsider until he was forced out of business. Then the production of the hollow blocks was geared down to its artificial level again and the production of bricks proceeded as before. Truly, it would seem that the hazards of the jungle of big business are still encountered by the intrepid explorer in search of new materials and techniques.

(iv) The finished appearance of concrete blocks cannot be compared with that of a good facing brick, neither can its weathering properties. But in Scotland there are little or no good facing bricks and if the walling has to be rendered or harled then it matters little what manner the wall is built in. Earlier descriptions and photographs have shown that it is possible to produce a faced concrete block that is reasonably acceptable in external appearance. Moreover this block-building technique has been initiated and developed successfully by an Edinburgh firm, originally the Scottish Orlit and now Scottish Construction Ltd. This firm has proved that block walling can be used instead of brickwork and, with careful organisation and planning, can be erected more cheaply than the conventional brick walling.
The work study in blocklaying conducted by the Building Research Station in 1948 was probably the most important full-scale experiment of this type during the post-war era. The results of the experiment comparing the productivity of blocklaying against bricklaying were well defined and conclusive, for it was clearly shown that common bricks took approximately four times longer to lay than large concrete blocks - reckoned, of course on the basis of equivalent volume. At the same time the gain in productivity in terms of volume of walls was offset by the proportionately higher costs of the concrete blocks, and the ultimate cost saving was consequently not so impressive as it might have been.

Taking a pair of houses built in brickwork throughout as a datum for cost comparison the final cost figures showed an approximate saving of £30 (£15 per house) when hollow clay blocks were used and also where the outer walls were built of 18in. by 9in. by 6in. light-weight concrete blocks. The test houses were situated near to the Fletton brickworks and brick prices were as low as they could be expected to be anywhere in Great Britain. It is more than likely that an experiment of this kind, if carried out in Scotland, would produce results even more favourable to hollow clay and concrete blocks.
All the data concerning large prefabricated wall units have shown that two major problems arise - firstly the location of the factory manufacturing the units and secondly the handling of the units from the point of manufacture to the final position in the wall. It is most essential that a factory turning out heavy concrete panels should be near to the site if not actually on the site, but this is only possible where the particular housing scheme consists of a very large number of houses concentrated in multi-storey blocks. The capital cost of setting up a factory on the site may be quite considerable.

When the wall units are made there remains the problem of placing them in position, without running up the cost of the building unduly by the extensive use of special hoists or cranes. Probably the most promising walling technique of the type under consideration is the "tilt-up" method of placing panels which have been cast horizontally on the floor adjacent to the wall position. This seems to be a most logical procedure and both Norwegians and Americans claim that the system is economic.

The cost saving reported by those responsible for lift-slab building in Norway was of the order of £50 per house. This was indicated in an official report issued by the Norwegian Research Institute.
In France the prefabrication of large concrete wall and floor units has been done on a large scale and convincing claims have been made for savings in cost compared against the in-situ technique. It has been found that prefabricated units can be made up, vibrated, etc. with far greater facility than in-situ members can be. This results in stronger concrete which in turn makes possible a quantitative gain in materials and labour costs. On the average building framed in reinforced concrete with large prefabricated wall units in concrete the savings in concrete materials are estimated to be 15% and manhours 10%. There is also a small saving of 2 to 3% in reinforcement, and the saving in shuttering on a block of flats costing some £100,000 has been estimated to be 10% to 15% of the cost of the complete job. The French authorities operating these prefabricating techniques are generally agreed that although there may be interesting possibilities and opportunities for cost savings on small jobs, of some £10,000 in value it will nearly always be the larger job of £1000,000 upwards that will realise significant savings and will permit redemption of cost for plant and equipment.
Non-traditional building in Sweden, employing large prefabricated outer walls has resulted in a saving of 66,000 kroner per house. These houses were completed recently at Vaxjo and comprised six blocks of flats on eight floors. The reinforced concrete frame and inner walls were of traditional construction and the outer walls, certain thin partition walls, the stairs, rubbish chutes and ventilation ducts were precast and placed in position by cranes.

Particular attention was paid to the planning of this scheme so that the cranes were constantly occupied. The blocks of flats were erected in pairs and the sequence of work arranged to permit an exchange of shuttering from one block to the other as the work proceeded. The site labour force was very small indeed for a project of this size, and consisted of fourteen unskilled workmen, eight carpenters, three crane drivers and three foremen.

This is only one of many Swedish schemes using large prefabricated sections with a view to economising in manpower and particularly in finishing work.
Interesting cost data have been provided in a report prepared in 1956 by the U.S.S.R. for the Working Party on Cost of Building set up by the Economic Commission for Europe. These data refer to the use of large prefabricated reinforced concrete panel walls in house-building and indicate that savings in labour resulting from the employment of this constructional technique against concrete monolithic and brick walling is of the order of 10% to 25%, after making due allowance for the labour employed in prefabricating the panels.

It is significant however that the Report does not claim that this sharply reduced labour expenditure has brought about a direct reduction in building costs, and it is apparent from this that the cost of prefabrication in the Russian factories has much the same effect in neutralising site economies as factory-prefabrication costs do in this country. But the Report quite rightly goes on to say that the cost of precast components is continually being reduced as production grows and as processes are improved.

The U.S.S.R. Report also supports the arguments that have been put forward elsewhere in this thesis, when it is claimed that the economies realised on the site have made/
made for a substantial reduction in overheads, and as a consequence of this it was claimed that a final cost reduction of 9.5% to 11% was achieved.

These considerable savings in man-hours and final costs are very impressive and make it quite plain that the use of large precast wall sections in house-building is well worth while. But it must be remembered that precast concrete house components were being used in Russia before the last war, and during these post-war years the equipping of factories for the mass production of these components has proceeded at a phenomenal rate of progress which is seldom seen outside totalitarian countries. Hundreds of plants were set up between 1945 and 1955, and following this a development programme was laid down by Government decree for "The Development of Production of Precast Ferro-concrete Structures and parts for Building". Under this decree a further 402 factories and 200 outside sites are to be built during the three years 1955-57, and will precast wall panels, floor panels, columns, stairs, landings and foundation blocks.

It is hardly likely that we shall see in this country, such a comprehensive network of Government sponsored precast concrete factories on any comparable scale, but these Russian experiments and experiences are nevertheless extremely valuable and serve to show quite conclusively that large-scale prefabrication of concrete components weighing up to 5 tons can reduce house-building costs.
Reference has already been made to the high cost of handling and placing large prefabricated concrete units and in addition to these costs consideration must be given to the expense of moulding the units. Precast panels must be accurate in size and shape and this means that the moulds must be made to very fine limits and must be framed so that they are completely rigid in order to resist the great hydrostatic pressure of wet concrete together with such vibration as may be employed.

A timber mould for a storey-height precast concrete unit could cost anything between £25 to £75 and a metal mould would cost twice as much. Timber moulds can rarely be used more than 30 to 50 times, though Wimpeys are getting about 50 castings from their no-fines plywood shuttering lining and a further 50 castings when the plywood is turned.

Metal moulds will give five or six times the castings possible for timber formwork but the initial cost and the lack of standardisation in house sizes tend to prevent contractors from purchasing large stocks of metal moulds which are seldom as adaptable to other purposes as timber moulds can be.
Wall panels of gypsum have been fully considered in Part One and there seem to be many interesting possibilities for development of this type of wall panel. At least three firms in Great Britain have experimented with gypsum panels and a great deal of research has been done by the War Department. On the whole there does not appear to be so much enthusiasm in this country for this walling technique as elsewhere in other countries. Patents for operating the Scottish (Bellrock) system have been acquired by organisations representing nearly twenty countries and now the Russians have inspected this Scottish factory manufacturing storey-height excellently finished panels and as a result of this inspection nine complete plants have been ordered for delivery to Russia. From what J. Lawrence (principal director for Bellrock) has said there is little doubt that the Russian housing authorities intend to develop this gypsum slab process and put it into operation quite extensively.

The Bellrock people claim quite emphatically that a single-storey bungalow type house, with external and internal walls of prefabricated gypsum, can be built at 10% less cost than by traditional means. The War Department has/
has costed twenty houses that were specially designed to incorporate storey-height prefabricated gypsum panels manufactured in a W.D. controlled factory. The final cost per house worked out at about £1840 each for a superficial area of 940 sq. ft., and allowing for the fact that reasonable opportunity was taken for a "trial run" to enable the workmen to get accustomed to the new technique, the final cost was somewhat disappointing. However, the W.D. observers were able to confirm the cost of the site factory and to estimate the cost of a factory capable of prefabricating gypsum panels economically for a £1m. contract at £20,000. This is a very large outlay but a contract of this size would undoubtedly justify such an outlay if all other considerations such as gypsum supplies etc., were favourable.

So far as this country is concerned the demand for gypsum panels will depend on a number of factors; the price and availability of gypsum, the supply of skilled craftsmen, scepticism in connection with the resistance of external gypsum panels (even when faced with a weather-resistant coating), etc. Of these factors, the one referring to skilled labour is very important, for we still have a strong labour force of plasterers in this country while other countries - particularly those who have shown themselves to be most interested in prefabricated gypsum panels - have not.
No-fines Concrete Walling.

This technique of construction, pioneered in this country by the Scottish Special Housing Association is now well established and has undoubtedly proved itself as an aid to productivity in housing work, particularly in Scotland where the scarcity of good facing bricks and unlimited supplies of concrete aggregates provide special opportunities for this type of poured concrete walling.

At least one other very large firm in Scotland besides the S.S.H.A. is operating this walling system and the differences between the two organisations' method of formwork, pouring, etc., are most interesting. It has been mentioned that the initial outlay on the massive one-piece forms is extremely expensive and it is not surprising that every effort is made to prolong the useful life of the formwork. Until improved forms of shuttering were evolved the capital cost and maintenance charges for formwork averaged out at about £37.10. per house. Now the S.S.H.A. is using a type of form which is made entirely of steel, the facing being 14 gauge perforated sheet mounted on a frame of rolled steel channels with steel angle stiffeners, all connections being welded.

These/
These all-steel forms have a much greater initial capital cost than the older types incorporating expanded metal and/or plywood fixed to wood framing, but it is claimed that the life of the steel form is almost indefinite and that maintenance is rarely necessary. The cost per house for capital cost and maintenance charges are stated to be much smaller than for timber framed forms.

Against these experiments and the general adoption of all-steel formwork by the S.S.H.A. it is significant that Messrs. Wimpeys are continuing to use a timber form lined on one side with plywood and expanded metal on the other and, apparently, continuing to make a profit on their no-fines housing operations. This firm (at the time of writing) is building no-fines concrete houses on an extensive estate at Liberton, Edinburgh, and the output of a relatively small labour force together with three cranes is quite remarkable compared with the progress of another firm on the same site engaged in constructing two-storey houses in traditional brick construction. The comparison is indeed so striking to even the casual onlooker that it must surely be plain to the bricklayers on the site that they are in danger of being supplanted by a concreting technique of house-
house-building that is dependent on only a very small percentage of skilled tradesmen linked with a comparatively larger proportion of unskilled building operatives earning an average of £20 per 70 hour week.

The no-fines concrete system attracts a high degree of mechanisation coupled with unskilled operatives on a bonus basis of payment and it is highly competitive with brickwork wherever circumstances are favourable to the no-fines technique. These circumstances exist where there are large sites containing a limited number of house types which have related wall sizes. Moreover there is little doubt that the economic advantage of this form of poured concrete walling will be enhanced in the event of a widening of the gap between skilled and unskilled building operatives' wage rates. These rates at the moment are ridiculously close to one another, and bearing in mind the differences between the time taken to produce a skilled joiner and that taken to train a building labourer, there is every reason to suppose that some adjustment of these rates will soon be made.

The organisation of no-fines walling is quite a simple operation for production, measured by numbers of houses according to their type is simply related to the/
the number of cranes used together with the right allocation of supplementary plant and equipment. This relationship can be taken as four houses per crane per normal working week for two-storey houses and three houses per week for three and four-storey flats.

The following examples of manpower expenditure from contracts completed for no-fines concrete houses have been supplied by the Chief Engineer to the Scottish Special Housing Association:

(a) 246 two-storey houses, 50% 2-bedroom, 50% 3-bedroom, average floor area 760 sq. ft. Average labour time per house for all trades, including underbuilding and site works, - 1,315 manhours. Average time to complete each house, 26 weeks.

(b) 78 three-storey flats, comprising 52 two-bedroom and 26 three-bedroom flats, average floor area per flat - 709 sq.ft. Average labour time for pouring exterior walls and cross-walls, all 12 in. thick - 123 manhours per flat or 1.15 manhours per sq.yd. measured across openings. (Crane hours were 17.4 per house, or 0.163 per sq. yd.). Average labour time per flat for all trades, including underbuilding and site works, 1,576 manhours.

These figures make a good case for mechanised methods of forming house walling in no-fines concrete.
Inner shuttering for "no-fines" houses, prior to erection on concrete base.

Inner shuttering in position, together with full provision for the various fixings, plugs, windows, etc.
Structural Framework and Structural Walling.

The skeleton or structural framework of a multi-storey block of flats may account for approximately 20% of the entire cost of the building. It is important therefore used in that the methods / constructing this frame are at all times subjected to careful and critical examination to ensure that the most economic method is employed. In the past there has, unfortunately, been a flagrant misuse of steel in many high buildings, resulting in a shocking wastage of one of this nation's most precious assets.

In this brief summary of the different types of structural framework and their relationship to considerations of productivity and cost it is not proposed to consider the influence of design factors on cost because that is beyond the scope of this study of new constructional techniques. The main intention is to underline what must be apparent to all concerned with high buildings - that a structural steel frame is indeed wasteful and that there are alternative methods which are satisfactory from all points of view and which use only a small percentage of steel or practically none at all.

Perhaps the most popular alternative to a steel frame/
frame is reinforced concrete, usually cast in situ. Such a framework should show anything up to a 30% saving against the cost of the erection of a steel frame together with concrete encasement to meet the requirements of the new model by -laws in connection with fire precautions. Also the time factor should not vary a lot between the two methods of framing when the fire casing of the steel is taken into consideration.

In a recent survey by the Building Research Station of 72 different blocks of flats ranging over London, the Provinces and Scotland, there were 7 blocks with steel frames: 13 in load-bearing brickwork, 51 in dense reinforced concrete and one in load-bearing no-fines concrete throughout. The cost of the steel framework ranged from 20/- per sq. ft. gross to 28/-, averaging at say 24/- per sq. ft. compared with an average of 19/9d per sq. ft. for reinforced concrete column and beam construction. This provides conclusive evidence of the economy of reinforced concrete framing.

Turning to the consideration of structural walling as a further alternative it is interesting to note that in the same B.R.S. survey of the 72 housing blocks there were included 35 blocks which relied on structural walling instead of/
of a frame. Sixteen of these were in reinforced concrete and averaged 19/10d. per sq. ft. gross, five were in a composite walling of reinforced concrete framing members and loadbearing reinforced concrete, and the cost was an average of 18/7d. per sq. ft.

Only one no-fines block was included in the survey. The block was 10 storeys high and the cost per sq. ft. came out well below the other concrete walling at 12/8d. Load-bearing brickwork was used on 13 of the 72 blocks and 11 out of the 13 were only six storeys in height. The average cost was 15/- per sq. ft. gross.

These prices which have been quoted for the various types of structural framework or structural walling have in all cases included the complete superstructure, otherwise there would have been some difficulty in comparing say, composite reinforced concrete against a steel or r.c. frame, for obviously the frame requires a cladding whereas the composite walling does not.

The prices per sq. ft. have also been average prices and in some cases this may not have done justice to certain forms of framing - reinforced concrete column and beam for example, where the range extended from one block at/
at 13/0d. per sq. ft. to 34/0d. per sq. ft. in the most expensive block. A summary of these costs is reproduced below so that the wide range of costs over the various blocks may be clearly seen.

<table>
<thead>
<tr>
<th>Number of Blocks</th>
<th>Type</th>
<th>Range of Costs per sq. ft.</th>
<th>Average Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Steel Frame</td>
<td>20/- to 28/-</td>
<td>24/-</td>
</tr>
<tr>
<td>30</td>
<td>R.C. Column &amp; Beam</td>
<td>13/- to 34/-</td>
<td>19/9d.</td>
</tr>
<tr>
<td>16</td>
<td>R.C. Walls</td>
<td>14/6 to 31/-</td>
<td>19/10d.</td>
</tr>
<tr>
<td>5</td>
<td>Composite R.C.</td>
<td>12/4 to 24/-</td>
<td>18/7d.</td>
</tr>
<tr>
<td>1</td>
<td>No-fines Concrete</td>
<td>12/8d.</td>
<td>12/8d.</td>
</tr>
<tr>
<td>13</td>
<td>Load-bearing Brick</td>
<td>12/6 to 17/6</td>
<td>15/0d.</td>
</tr>
</tbody>
</table>

This summary shows that, at 13/0d. per sq. ft. the reinforced concrete column and beam construction is well below the lowest of the steel framed blocks and is nearly down to the no-fines cost. And against the no-fines method the reinforced concrete column and beam construction could be employed quite safely at most heights, but very careful supervision is essential on no-fines concrete work in excess of five storeys or so.
An interesting development has recently been reported in connection with high tensile steel sections used in the structure of commercial buildings. The steel is known as "cor-ten" low alloy steel and has certain advantages over ordinary structural steel. It is claimed that the yield point is approximately 50% higher than that of ordinary steel and this is accompanied by an improved ultimate strength and fatigue resistance.

This high grade steel is made up into cold formed sections which are used in prefabricated three-pin arch-type trusses. These trusses are placed at 20 ft. spacings along the building and linked up by purlins which are also in cold-formed high tensile steel. The trusses are placed by five men and two mobile cranes in a planned sequence of work that is claimed to achieve the erection of the building framework on prepared foundations at a speed of 1,000 sq.ft. per hour, cutting building time when compared with ordinary methods by at least 30%.

This technique of construction of a framework is certainly more economic of steel than the normal steel-framed building and a 10% saving in cost is claimed. But I doubt very much whether this technique of the three-pinned arch could be applied to low-cost housing, for it would only be applicable to 2 or 3-storey work which normally does not require a structural frame.
(Additional Data on the use of Climbing Shuttering)

The climbing shuttering method of concreting walls has been used in this country, mainly in Liverpool, for the erection of grain silos, but it is only quite recently - in August 1956 - that this technique has been employed on housing. This interesting project was the new Nurses' Home at Victoria Hospital, Kirkaldy, Fife, and the loadbearing walls were erected in the short space of 3½ days.

The base of this five-storey building consisted of an open form of ground floor storey built by normal methods of heavy reinforced-concrete portal frames enclosing an open area for recreational purposes and supporting the first floor. The rest of the structure is based on the "crosswall" principle and all the loadbearing walls, external and internal, were formed by the climbing shuttering.

The contractors responsible for this building - Stuart Construction Co. Ltd. of Glasgow - had no previous experience of this method of sliding shuttering and consequently had many initial problems to solve, particularly in the construction of the 4 ft. deep formwork and the assembly of it at the initial first floor level. Great care had to be taken to arrange for just the right amount of inclination/
inclination from the vertical between the bottom of the wall slots and the top of them. The walls were generally 6 in. thick and it was essential that the openings in the formwork at the bottom were \( \frac{1}{3} \) in. or so wider than at the top, otherwise the timber shuttering would "drag" unduly against the side and create friction and disturbance of the finished concrete surface.

Altogether the great "platform" of movable timber shuttering took four weeks to assemble and cost over £4,000. Great care was taken to check and rehearse - as far as possible - every phase of the pouring operation, for it is absolutely essential that the shuttering, once launched, shall travel continuously for several floors at least, and preferably right up to the roof level. If work is stopped and the concrete is allowed to set within the confining formwork, there is obviously great difficulty in moving the formwork again without pulling it apart. On this particular job the pouring was continuous for four days and three nights, the work at night being done under floodlighting.

Some 120 jacks were used to raise this immense platform of shuttering and these jacks were controlled by three/
three men operating from a central control cabin on the platform.

At the moment of writing, November 1956, no accurate costs were available, but the general opinion was that a five-storey building could not achieve optimum economy in the application of a technique of poured concrete walling such as this where the initial preparation was so very costly. Clearly the shuttering - once pouring had commenced - could climb ten or more storeys at 6in. per hr. just as easily as it had climbed five storeys. The higher the building goes - the more justification there is for the high initial cost of preparing the formwork, which in this instance was over 130ft. by 36ft. and, as has been stated, cost over £4,000.

During the progress of the Kirkaldy job there were obviously many teething troubles that cost money to overcome. The weather in August 1956 will long be remembered as being responsible for a succession of rainy days and this meant that the rate of travel of the shuttering had to be slowed down to permit the concrete to set sufficiently whilst passing through the shutter to stand on its own afterwards. Even in favourable weather circumstances the rate/
rate of travel of the formwork was restricted to 6in. per hour so that the concrete was contained for 7 to 8hrs. within the formwork which was 4ft. deep. Yet American contractors, with the advantage of a superior "know how" through long experience of this technique are able to work on a rate of travel of 12in. per hour.

To achieve maximum savings in cost with climbing shuttering it is essential that the formwork should be the platform from which everything is done. The external wall surface should be left as from the shuttering and possibly a lining provided afterwards on the inner surface of the walls. But on this Scottish project the external walls were cladded in facing brickwork and precast panels of concrete faced with Aberdeen granite chippings. So it was necessary to erect an expensive system of external tubular scaffolding, and in addition to this there was the cost of building in fixings for the cladding while the pouring went on.

Lack of experience of this type of work caused the contractor to insure against delays or breakdowns by putting more than the necessary number of workmen on the job. There were 50 men employed on each shift. Another instance of unforeseen/
unforeseen cost was the necessity for paying the workmen for five full nightshifts when only three were taken up during the pouring operation.

Now that the contractor has had this experience of climbing shuttering he is naturally anxious to obtain other contracts involving work that will enable him to apply this experience in the interests of building economy and his own profit. It is to be hoped that he may be given the opportunity to build some of the new high flats that are shortly to be offered for tender by the Edinburgh Corporation.

The Kirkaldy flats photographed 14/11/56 when the brick cladding was in progress.
Enamelled sheet claddings have been examined briefly in Part One, and in this summary it will not be possible to give examples of productivity or cost with regard to the application of this kind of material to housebuilding because so little of it has been used in this country. Some time before the war, enamelled metal panels were designed for the L.M.S. by Dr. Martin and Llewellyn Davies but the panels were employed to a limited extent only on an experimental station.

The porcelain enamel industry in America has steadily increased its output from $1 million in 1940 to $25 million at the present time and the forecast has been made that in ten years time there will be more porcelain enamel in American buildings than in household appliances today.

The cost of porcelain enamelled steel cladding in America is estimated at approximately $1.40 per sq. ft. and when an aluminium base is used the cost goes up to $2.50 per sq. ft. Comparing either of these rates with about 5s. per ft. super for conventional cavity brick walling in this country is very difficult for American costs cannot be simply...
simply equated with costs in this country. But when due allowances are made for the higher cost of American labour and the lower cost of the American material on account of what is almost bound to be a higher output and a far greater standard of industrialisation, then the indications are that porcelain enameled sheets are unlikely to be widely used in British house-building in the near future.

For an approximate idea of the cost of a curtain wall of prefabricated aluminium panels, reference has again to be made to American experience. A 26 storey building in New York City was recently sheathed in aluminium panels covering 98,363 sq. ft. of wall in 6½ working days. The work was done at the rate of three minutes per panel and at a cost of $6 per sq.ft. of wall surface. Here again the cost is high, much higher than enameled steel panels, and the monotonous self colour of aluminium presents a difficulty that can be got over only by colour anodizing which increases the cost of the aluminium cladding even more.

It would appear then that, as a cladding for low-cost housing construction, aluminium is unlikely to be considered at the present time.
Various claims, some rather extravagant, have been made for a substantial saving in the weight of the structural framework of a building through the use of lightweight claddings. For example it has been stated that in an office building recently erected for the Aluminium Company of America the total weight of structural steel was reduced by half, due to the use of aluminium cladding panels. In support of this claim the following comparative figures were given - "The Alcoa building contains 310,000 sq.ft. of rentable space above the first floor and required 6,500 tons of steel. A conventionally constructed skyscraper nearby, the Gulf Building, with 304,000 sq.ft. of floor area required 12,700 tons of steel."

These figures were given by a well known architect in this country and while it is not suggested that they are inaccurate it does seem more than likely that the people responsible for the Alcoa building took very special pains to make this remarkable comparison possible, mainly in the interests of publicity for aluminium and, perhaps, not altogether in the interests of actual cash savings!

It is a little difficult to understand how the cladding to a framed building can have such a substantial influence/
influence on the design of the greater part of the framework for in most framed structures it is the combined superimposed and dead loading on floors which has the greatest influence on the design of steelwork or reinforced concrete framing. It could be conceded that the stanchions located in the external walls will be a little lighter in section owing to the reduced loading transmitted to them from the beams supporting the lightweight claddings, and these beams would also be lighter in section. But surely these economies in the outer members of a large building cannot be said to account for a 50% saving in the total amount of steel in the entire frame. It is more than likely achieved that the Alcoa building/the greater part of this remarkable saving through the use of aluminium or other light alloys in the construction of the floors, partitions, etc.

I would agree that the use of lightweight claddings can effect an overall saving in the cost of a structural framework, but probably not more than 15% or 20% at most. There are however, quite significant economies which may be realised from the reduction of the size of the foundations supporting the external columns that are carrying the reduced loads due to lightweight claddings.
The use of lightweight claddings is also complementary to the technique of cross-wall construction and thus makes a significant contribution to economic building.

There is still very much more to learn about the behaviour of new types of claddings and in view of the experiences of the Americans on the Lever building and others it is not difficult to understand the "ca canny" attitude of the Scottish architect or contractor when any departure from traditional methods of construction is contemplated. The use of glass as a wall cladding has been tried out in England on many types of buildings including flats, and where the method of construction has restricted the glass panels to reasonable sizes contained within proven methods of patent glazing bar there has been little trouble. But there are already a number of buildings in England which have experienced failures of large areas of glass cladding through fracture, particularly where coloured glass has been used.

These failures have been sufficiently numerous to cause the London County Council to inform the R.I.B.A. that, following the number of failures in the fixing of cladding on buildings, the L.C.C. were proposing to make certain amendments to the by-laws to provide a check on methods of fixing.
Concrete in General Use.

The notes on Cement and Concrete in Vol.1 of Part One dealt first with cement and some indication was given about the possibility of economy through the use of cement adulterated by "fly ash". Up to 20% saving in cement seems to be possible under certain conditions and the data given in graph form on laboratory tests of the adulterated cement suggest that the loss of strength might not be unduly significant on mass concrete dams where the retarded setting action is advantageous, but in house-building the addition of the adulterant might not be worth while.

Bulk cement handling is not over popular on the large housing sites in the S.E. Scotland area but this is probably due to the distance that pressurized tankers would have to travel from the cement works in England to the distant Scottish site. This remoteness in relation to the area where the cement is made has made more difficulty for Scottish contractors when supplies are scarce and shipments of English cement have to be replaced by cargoes from Belgium, Germany or Sweden.

The development of improved methods of mixing and
It is reckoned that something like 25/- per ton of cement is taken up in the cost of the paper bags, and in operating a system of bulk cement handling this saving would be apportioned between the contractor and the cement company on a 50:50 basis. It has further been calculated that the capital cost of a special tanker for bulk cement delivery could be made out of the cement company's saving on bags in the matter of six months.

There would have to be an appreciable saving from the contractor's point of view because he is responsible for the provision of special storage facilities costing probably £12 to £15 per ton of cement hell. A simple calculation shows that a consumption of 10 tons a week would effect a saving of £5 or £6 a week, and this would pay off the capital cost of a ten ton silo in a matter of 20 weeks or so, and thereafter the saving would all go to the contractor. There is also the indirect saving through the convenience of having the silo loaded by tanker instead of the expense of having labourers carry in the bagged cement to the storage hut, and finally there is the economic advantage of drawing cement from the silo in precisely measured amounts that can be varied according to the mix ratio.

The/
The City of Leeds Highways Dept. recently operated a scheme providing for the bulk storage and conveyance of cement to an existing weigh batching plant. This was probably the first plant of its kind to be operated by a local authority in this country and was devised in order to guard against possible shortages of cement and to save the high cost of bags. The saving due to the installation of the bulk cement storage plant and to the central mixing plant was estimated to be £2,500 per year, this saving was of course, due mostly to the central weigh batching plant but the bulk cement storage certainly accounted for a substantial cash saving.

At the time of writing these notes, the development of bulk handling of cement on a national scale is planned by a new company recently formed for the purpose. In the early stages, special tankers and other equipment are being brought in from Germany but the compressor and jet equipment is to be made at Bellshill or elsewhere in Scotland. It is to be hoped that this plan on a "national" scale includes Scotland and is not, as so often happens, restricted to the national borders of England. Bulk cement can surely be shipped to the Forth and the Tay and the Clyde and unloaded directly into "tanker" lorries.
There seems little doubt that, given the right size of job and other favourable conditions, the bulk handling of cement can bring about substantial economies in cost. In the Scandinavian countries this technique of handling cement has been widely employed for some years and in Europe, particularly in Italy, it is quite common to see the cement silo on the larger building sites. The photograph is of a multi-storey housing scheme in Milan.

The following figures confirming the cost savings claimed on Swedish building sites from the use of bulk cement are taken from the Swedish publication "Cement och Betong". The reduction in cost by which bulk cement users benefit is about 3.50 to 5.0 kroner per ton and sometimes even more, according to local conditions. With a consumption of 10 tons per day on a site, there is a direct gain of 35-50 kroner, or, on a normal house-building site with a total cement consumption of about 300 tons, a gain of 1,000-1,500 kroner, or approximately £100.
The development of improved methods of mixing and an ever-increasing stock of knowledge of the part played by aggregates in the production of high quality concrete has assisted productivity in house-building to a marked degree. The control of concrete by quality rather than by the older method of control by specification has assisted the simplification of site supervision and has put the contractor on his mettle, so to speak, by leaving the selection of aggregates, proportions of mixing, etc., to him — subject to the requirement that the concrete shall stand $X$ lb./sq. in. at seven days and $Y$ lb/sq. in. at twenty eight days.

The mix-design data and test results shown in Vol. 1 of Part One indicate fairly conclusively that the cement content in a concrete mix may be reduced from 10% to 20% or 30% by scientific grading and control of water/cement ratio. Also, with the greatly increased working stresses made possible by the vibration of concrete, the spans of slabs and beams can be considerably increased or alternatively much lighter sections may be used.

The addition of calcium chloride during the mixing of concrete has been widely practised by Scottish contractors during winter months when frost was expected. But one large contractor building houses of "no-fines" concrete/
concrete houses in the Edinburgh area has continued the use of the calcium chloride throughout the summer of 1956, not, of course, because frost is anticipated during a Scottish summer, but on account of the faster turnover of shuttering achieved by using a concrete containing an accelerating agent. Messrs. Wimpeys have established the firm fact that it is cheaper to hasten the set of concrete in first and second floors by adding a comparatively inexpensive chemical and thus be able to strike the formwork after two days and use the shuttering again. With the general run of timber formwork this is quite understandable for it is extremely difficult to get more than 15 to 30 uses out of a close-boarded set of floor shuttering on an average housing site, and softwood is one of the most expensive materials on a building site.

The future development of concrete has horizons so distant as to be incapable of definition at the present time. It is probable that we shall see a more intensive application of the "vacuum" process of consolidation in which excess water is drawn from the concrete while compaction takes place through the action of atmospheric pressure.
pressure.

This system of compaction was used on the large precast concrete units used in the floors of the L.C.C. Picton St. Flats scheme, and an extremely fine surface was obtained throughout.

The use of ready-mixed concrete on a central site in a large industrial area where there are many congested sites gives considerable scope for the saving of labour and for the precise proportioning and mixing of the concrete. This technique was one that was surveyed by the British Productivity Team when visiting America several years ago, and the team recommended in its report that the technical possibilities of ready-mixed concrete should be looked into.

Since this recommendation was made, a number of central mixing stations have been set up, mainly in London. The dry materials are mixed in the central stations and special lorries with rotating containers carry the concrete to the point of application and water is added during transit. The resultant concrete is generally admitted to be superior in quality to site-mixed material, particularly where the site is on the small side and the/
the arrangements for concreting are rudimentary.

For a congested site in a large city the advantages of ready-mixed concrete are obvious - no mixing plant or labour is required on the site and the transport of the concrete may well be arranged so that the incoming lorry discharges the load directly into the trench or formwork. This could only happen in isolated instances of course, and usually at ground level. Other advantages are the removal of the necessity to find room for huge heaps of aggregate and cement storage huts. Also it is found that the clerk of works' or other responsible people on the various sites have less trouble in having their requirements met by the really uniform quality of the ready-mixed concrete than by a concreting gang on the site with a constantly changing personnel and possibly an indifferent concrete supervisor who has other things besides concreting to supervise.

Ready-mixed concrete is 5/- to 10/- dearer per cubic yard as a general rule but it may be worth while using it (1) if it essential to save time and arrangements are made for rapid placing, (2) where the site is congested and (3) when it is important to avoid delays owing to adverse weather conditions. The travelling distance should generally be under 20 miles.
A central depot supplying ready-mixed concrete has been set up in Glasgow by Messrs. K.&C. Jaeger Concrete Co. Ltd. This firm is supplying an average of 200 cubic yds. a day to all types of building and civil engineering sites around the city. The cost of ready-mixed concrete supplied by this firm depends on the distance to the point of delivery and the total quantity involved, but as an example a 4:2:1 mix by weight 1\frac{1}{2}\text{in.} down washed sand and gravel aggregate might cost from 70\/- to 79\/- depending on the factors mentioned.

This Glasgow firm has in its factory a fully equipped laboratory concerned with the control of quality of all materials and of the finished concrete. In addition to this, experimental work is constantly carried on to establish the merits of the latest trends in concrete technology. The concrete supplied varies from normal structural concrete to special mixes including refractory concretes to withstand specified temperatures, granolithic concrete for floor screeds and mixes with special properties e.g. acid resistant, water-proofed, rapid hardening, slow setting, etc.

It is unfortunate that firms like this are not yet operating in Edinburgh and other large Scottish towns, though I understand that Messrs. Jaeger are considering the prospects in Edinburgh at the present time.
Productivity Through Repetition

The operation of a new constructional technique, whether it is applied to poured concrete walling, prefabricated plumbing assembly, precast concrete construction or any other aspect of building is bound to become more productive as the process is repeated over and over again by the same team. From careful site observation on selected housing sites in Germany it has been conclusively shown that substantial increases in productivity can be realised by planning buildings in such a way that constructional processes such as the erection of formwork can be repeated many times in the same building and by the same team.

For example, the time taken on foundation work on a site in Hanover was reduced 30% after three-fold repetition and as much as 50% when repeated seven times. In walling the time taken to place storey-height prefabricated units was cut down by 35% after the process was repeated for the seventh time. In flooring the saving in time varied between 30% to 45% after six-fold repetition.

Rate/
Rate of productivity is immediately affected when changes in size, shape or method of construction are introduced and also when changes are made in the membership or organisation of the team.

Multi-storey buildings are specially suited to repetitive work. In these German operational studies it was found that the repetition of work in each vertical floor lift could achieve reductions in manhours from 100% on the ground floor to 75% on the fourth floor, but the advantages of repetition were seen to diminish as the building progressed beyond five storeys. Some indication of this is given in the table set out below. The building was nine-storey, concrete framed, and the figures given are manhours per cubic metre of concrete framework.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Shuttering</th>
<th>Placing reinforcement</th>
<th>Placing concrete</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>11.82</td>
<td>5.52</td>
<td>4.06</td>
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</tr>
<tr>
<td>First floor</td>
<td>10.88</td>
<td>5.32</td>
<td>2.50</td>
<td>20.0</td>
</tr>
<tr>
<td>Second floor</td>
<td>13.02</td>
<td>3.20</td>
<td>3.98</td>
<td>20.3</td>
</tr>
<tr>
<td>Third floor</td>
<td>9.52</td>
<td>3.60</td>
<td>3.88</td>
<td>17.0</td>
</tr>
<tr>
<td>Fourth floor</td>
<td>9.44</td>
<td>3.70</td>
<td>4.06</td>
<td>17.2</td>
</tr>
<tr>
<td>Fifth floor</td>
<td>9.40</td>
<td>3.88</td>
<td>3.72</td>
<td>17.0</td>
</tr>
<tr>
<td>Sixth floor</td>
<td>10.10</td>
<td>3.88</td>
<td>3.27</td>
<td>17.8</td>
</tr>
<tr>
<td>Seventh floor</td>
<td>10.70</td>
<td>3.68</td>
<td>4.22</td>
<td>18.6</td>
</tr>
<tr>
<td>Eighth floor</td>
<td>12.00</td>
<td>3.92</td>
<td>4.68</td>
<td>20.6</td>
</tr>
</tbody>
</table>
In the notes on Cement and Concrete in Vol.1 of Part One, reference has already been made to the urgent and pressing need for the proper training and certification of concreting supervisors and in Vol.2 there have been many references to new methods and applications of "in situ" and pre-cast concrete. It is manifestly impossible to realise the full economies from these new techniques unless men are trained in the art and practice of mixing and placing concrete. Since the City & Guilds of London Institute set up a recognised qualification in Concrete Practice and technical colleges have organised courses in preparation for this qualification there has been an ever increasing number of enrolments for these courses.

Following the first examinations in 1955 for the Certificate in Concrete Practice (Grade 1) the syllabus has been extended to include a Grade II Certificate. This extension of the original course has been criticised by some who argue that the scheme as it now stands is too ambitious and is going over the heads of the ordinary site concretors for whom the qualification was originally designed. I feel bound to agree that this criticism is well founded, for from my own experience of examining Grade 1 candidates in the oral/
oral section of the examination I would say that few of them could ever hope to obtain a pass in the Grade 11 examination.

Although the total number of passes in the examinations held so far is above 300 it is clear that this total compared with the total number of concreting supervisors throughout the country must be very low indeed, and while this discrepancy between the number of trained and untrained supervisors exists there is little prospect of persuading structural engineers to design to the higher stresses envisaged in reinforced concrete regulations and they will continue to work to "safe" margins which are wasteful of materials and manhours and have the effect of cancelling out or reducing any looked for savings from the application of new concreting techniques.

It seems fantastic that these opportunities which exist in Scotland for training in concrete practice are not grasped in both hands by the industry, for here is a sure means of improving productivity without specialised and expensive equipment. One would imagine that the employers' federations would combine with the colleges in the organisation of courses during the day with compulsory attendance, but as matters stand it is left to the employee himself to attend during his own time and to seek his own reward for doing so.
**Mortar Plasticisers.**

Workability aids for mortars are still not generally accepted throughout the industry though there seem to be more and more proprietary plasticisers appearing on the market every month or so, and the claims made by the various manufacturers about the effect of their particular plasticiser on productivity make interesting reading but are seldom supported by test results published by an independent authority. (Some test data were set down in Vol.2 to Part One.)

The National Federation of Building Trade Employers in England has undertaken to obtain some systematic observations on full-scale applications of mortar plasticisers to determine among other things whether the advantages claimed in preliminary trials are realised in practice and to get some indication of the degree of cost saving or otherwise. At the time of writing there has been no precise information issued on the cost aspect.

A demonstration testing the productivity potential of a mortar plasticiser produced by F.E.B. (Great Britain Ltd.)/
Britain) Ltd. was staged by that firm in the South of England quite recently. The demonstration took the form of a race, first between two bricklayers and then between two plasterers. All craftsmen were stated to be of comparable ability. The two bricklayers were given ten minutes in which to lay as many bricks as possible - one bricklayer used a mortar mix with plasticiser added and the other used a cement/lime/sand mix. The demonstrations were held at three centres - Dorking, Croydon and Eastbourne with different pairs of craftsmen competing. The results were as follows:-

**Bricklayer using mortar gauged 1:6 cement/sand plus plasticiser:**

Centre 1 - 81 bricks  
" 2 - 98 "  
" 3 - 99 "

**Bricklayer using mortar gauged 1:1:6, cement/lime/sand and no plasticiser:**

Centre 1 - 59 bricks  
" 2 - 75 "  
" 3 - 73 "

The results of the plastering trial were as follows:-

**Plasterer using 1:6 cement/sand with plasticiser**

rendered 7 sq. yds. at Centre 1 in 7 minutes  
" 2 in 5½ "  
" 3 in 5½ "  
All ruled off.

Plasterers using 1:3 cement/sand, no plasticiser, could not complete 7 sq. yds. within 10 minutes at any of the three centres.
Wall Finishes.

Apart from the limited use of mechanical methods of plastering and prefabricated concrete panels with exposed aggregate facings the external finishing to walling in Scottish housing has changed very little and we still see houses going up by the thousand outside Glasgow and Edinburgh, with the traditional drab "harling" in almost all cases. It is unfortunate that more extensive use could not be made of the oil shale bricks for facing work. These bricks are reasonably uniform in shape, texture and size, and have a uniform mauve colour which is not unpleasing. They cost only 103/5d. per thousand against local common "Coal Board" bricks at 128/- per thousand so it can be seen that there would be quite a worthwhile reduction in cost if these bricks were used as facings, and in addition to this the general external appearance of the new houses should be greatly improved.

Internal wall finishings have tended to change rather more than external finishings because new and improved materials have made it possible to use thinner coats of plaster and have considerably reduced the setting time/
time between coats. The use of plaster board with a single skim finish is used quite often on housing work in S.E. Scotland and in a number of instances a Vee-jointed insulation board is used without cover strip or skimming. The elimination of the wet plaster finish is indeed very desirable, for apart from the introduction of unwanted moisture into the fabric of the house and the time taken up in its evaporation there have been many time-wasting and expensive delays in house-building owing to the scarcity of plasterers. It is however, very difficult to develop a low-cost dry finish to house interiors without using cover strip or an exposed Vee-joint, and it has already been stated that the breaking up of wall and ceiling surfaces into permanent panels imposes an unwanted discipline on decorative style.

I consider that it should be possible to attain a higher rate of productivity in plastering if wall surfaces were built to finer limits so that the plaster thicknesses could be reduced to something between $\frac{1}{4}$in. and $\frac{3}{8}$ths.in. It would reduce materials and application times considerably. It might also be possible to develop a stout type of building paper that could be fixed direct to an accurate wall surface, using one of the modern synthetic glues to ensure permanent bond between wall and paper. This would be a dry and fast operation and would provide a good base for decoration.
The references made to mechanical aids to plastering interiors have made it evident that there is no immediate likelihood of its general popularity in this country, at all events in Scotland, for some time to come. The equipment that was tried out in Scotland by Messrs. Wimpeys was, I understand, of German manufacture, and the result of this trial was reported as unimpressive.

Quite recently, however, a new type of compressed-air roughcast and plastering equipment has been developed and marketed in Great Britain. The principle of the operation of this machine is the forcing by jets of compressed air; the plaster being first deposited on a trough fixed in front of the jets. The trough is filled from time to time from a wheelbarrow or other form of bulk container that can be moved around to suit the particular position of the operative with the plaster projector.

For ordinary thicknessing coats a labourer applies the plaster to the wall and is followed by a plasterer who wood floats it. It is claimed that a team such as this can apply between 30 and 35 sq. yds. of plaster coating per hour and work can be carried out simultaneously by other operatives on different levels, all working from the main air feed.
A large American firm specialising in plastering work has developed a system of scheduled operations that has resulted in appreciable savings in both material and manpower. The preferred size of housing scheme has been worked out at about 150 houses or so; a group of six plasterers is divided into two-man teams, one team working on the lower part of the interior walls, the other two teams working off scaffolding on the upper part of the interior walls and on the ceilings.

In addition to this group of six plasterers a second group of plasterers assisted by one labourer applies the skimming or finishing coat. This group of plasterers consists of two teams, each of two men, and they work on two separate houses, one team on each.

The table set out below shows how a total of 102 manhours is made up by each team. The table indicates that the six plasterers are assisted by three labourers, one of whom is responsible for the scaffolding, the other for mixing the plaster and the third one for carrying the plaster to the point of use.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Labour Force</th>
<th>Manhours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratch coat/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Operation | Labour Force | Manhours
--- | --- | ---
Scratch coat | One team of two men | 2
Floating " (Upper) | Two teams of four men | 16
(Lower) | One team of two men | 12
Also three labourers assisting on all the a/n work. | | 30
Skimming coat | One team of two men and one labourer | 28
| | 14

Total | | 102

It will be seen that the table includes for three-coat plaster work, though two-coat work is more usual in America for brick and block walling, as it is in this country. This particular firm used mechanical means of mixing the plastering material and conventional methods of applying it to the wall. Mechanical sprays for applying the plaster had been tried but it was found that the main drawback of the machine arose during low temperatures when the plaster froze at the nozzle.

A total of 102 manhours for a small house is far less than would be taken in this country on three-coat work. The figure would be more likely to be 150 to 200 manhours on a comparable house.
The respective merits of the traditional wooden joist and boarded floor and the solid floor were fully dealt with in Part One and some comparisons of cost were given. It is evident that the average contractor in Great Britain is much more familiar with the suspended wooden joist floor rather than the suspended reinforced concrete or other similar floor. Oddly enough, few contractors are able to design sizes for a suspended timber floor but they have great faith in their ability to select suitable joist sizes and do so without any qualms. But the same contractors would rarely dream of selecting an effective depth and reinforcement area for a suspended concrete floor and would expect the floor to be fully designed and detailed by a structural engineer. Even the architect is seldom qualified or confident enough of his ability to design a simple reinforced concrete floor for a repetitive house plan in a multi-storey building, and the cost of the work is increased by the structural consultant's fees.

It is true, of course, that in a multi-storey buildings, the structural engineer will usually be designing/
designing the framework of the building and therefore will expect to include the design of the floors in his calculations - though there's nothing to prevent the architect from designing and detailing simple floor spans himself! In two and three-storey housing work where the walls are loadbearing and concrete or composite floors are required there should rarely be any necessity for a consultant structural engineer.

The incidence of fuel costs in the heating of houses is seldom taken into account now-a-days when a building is being planned. This is not to say that architects do not give thermal insulation full consideration but to argue that the capitalised cost of extra fuel necessary to a poorly insulated building is rarely shown against the cost of the building. It is obvious that the cost of fuel is likely to increase while the cost of good insulating materials may always come down if the demand makes economic production worth while.

The ventilated timber construction on the ground floor causes a very rapid heat loss and does not compare well in this respect with a suitably finished solid floor. Moreover, the timber floor at ground level is so vulnerable to the scourge of dry rot, so prevalent in the large Scottish cities.
If due regard is paid to the poor insulation value and to the long term cost of maintenance or replacement of timber-joisted floors, and also to the tenant's expenditure on the provision and upkeep of linoleum or similar covering, there seems to be little doubt that the economic choice for ground floor construction should incline towards the solid concrete type with a suitable finish.

As to upper floor construction the need for a good standard of fire resistance is bound to place limitations on the use of suspended timber floors, though they can compare favourably against the cheapest of the fire-resisting types such as precast or in situ concrete. In the analyses set out in Appendix A it has been shown that a suspended wood joist floor in low-cost housing can cost as little as 10/7½d. per sq.yd. and this could hardly be improved upon by any other material or technique. But this is a floor which is suitable only for two-storey houses or for the intermediate floor in maisonettes as used in the L.C.C. Picton St. development (these floors were prefabricated in sections).

In ordinary suspended floors between separate flats/
flats, some provision is essential for deafening (sound insulation), and this causes the unit cost to rise sharply as may be seen in the analysis of the three-storey no-fines flats in Appendix A, where the cost per sq. yd. came out at 28/5d. per sq. yd., the deafening accounting for 57% of this total.

Suspended timber floors are limited generally to a 12 ft. or 14 ft. span. Beyond this the size of the joists would be such that the cost of the floor would rise so sharply as to be out of all reason. Yet in a prestressed concrete plank floor, spans of up to 18 ft. can be provided in a total floor thickness of five inches, and larger spans than this can be achieved with precast prestressed inverted T-section beams.

It has been shown in Part 1 Vol. 2 that these composite floors made up from prestressed beams are not perfect by any means. Many are subject to cracking from deflection or unequal moisture movement, and many of the thinner plank floors suffer from a poor standard of sound insulation. Yet, from the point of view of fire resistance the concrete floor, in one form or another, is most likely to be preferred between separate dwellings in multi-storey buildings.
The following cost analyses of two methods of floor construction make an interesting comparison. In the first analysis a solid floor finished with thermoplastic tiles is compared against a traditional type sleeper joist ground floor. This analysis is based on figures given by a firm manufacturing thermoplastic tiles.

The second analysis was prepared by the Timber Development Association and is naturally in favour of the timber sleeper joist floor.

It is obvious that a certain amount of bias has influenced quantities and cost in each analysis. It will be noted that although the area of floor is almost identical, the first analysis provides for eight air bricks against five in the second analysis. Then the exponents of the solid floor assume that a minimum of 5 sq. yds. of half brick walling will be necessary for sleeper walling while the second analysis makes the bare allowance for single bricks supporting each joist instead of the usual sleeper walls.

There is also a substantial difference between the necessary excavation estimated in the former case than in the latter. Also the quantity surveyor who prepared the analysis for the thermoplastic tile manufacturers included for 4 ft. cube of softwood in 3 in. by 2 in. plates on the sleeper walls. This is a fair allowance so far as Scotland/
Scotland is concerned because wood plates on sleeper walls are quite usual (though not nowadays 2" in thickness). But in England it is not generally the custom to use wood plates and therefore the second analysis by the T.D.A. is quite correct in omitting this item.

There are many other examples of intentional exaggeration in these analyses, but having regard to the undulating nature of building sites in general, and the irritating tendency of contractors to excavate far more than is necessary from under suspended timber floors, the opinion here is that solid ground floors on an average site are quite definitely cheaper than suspended timber floors.
## COMPARATIVE COSTS FOR SOLID GROUND FLOOR AND BOARDED SLEEPER JOIST GROUND FLOOR.

### SOFTWOOD BOARDED FLOORING ON SLEEPER JOIST AND WALL CONSTRUCTION REQUIRING SURFACE EXCAVATION.

**ANALYSIS NO.1**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 yards sup. Excavate vegetable soil over site average 6 in. deep remove and deposit not exceeding 100 yards run</td>
<td>1/4</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>7 yards cube. Excavate to reduce to levels and get out</td>
<td>5/9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>7 yards cube. Remove surplus excavated material and deposit not exceeding 100 yards run</td>
<td>6/-</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>31 yards sup. Bed of clinker ash 3 in. thick well rolled to receive concrete including levelling and ramming ground under</td>
<td>2/3</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>3 feet sup. Bed of hardcore well blinded on top consolidated to 9 in. total (finished) thickness for concrete hearths</td>
<td>1/2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>31 yards sup. Concrete (1:3:6-1½ in. aggregate) bed 4 in. thick spread and levelled on ashes (measured separately)</td>
<td>6/3</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>7 feet sup. Concrete (1:2½:5-3 in. aggregate) bed 4 in. thick as hearths on hardcore (measured separately), finished smooth including any form-work required</td>
<td>1/7</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>5 yards sup. Half brick wall in Flettons in cement mortar (1:4) in honeycombed sleeper walls</td>
<td>12/7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5 feet sup. Ditto in fender walls</td>
<td>2/-</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>88 feet run. Bituminous felt damp proof course and bedding in cement mortar on 4½ in. walls 3d.</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>88 feet run. Bed plate in cement mortar (1:4)</td>
<td>3½d</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Item Description</td>
<td>Rate</td>
<td>Quantity</td>
<td>Total</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>-------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>28 feet run. 3 in. agricultural drain pipe and bedding in hardcore, etc. as air duct</td>
<td>1/-</td>
<td></td>
<td>8:0</td>
</tr>
<tr>
<td>No. 6 Hole through 4½ in. brick wall for 3 in. drain pipe and make good</td>
<td>1/-</td>
<td></td>
<td>6:0</td>
</tr>
<tr>
<td>No. 8. 9 in. x 3 in. terra cotta air bricks and building into 11 in. cavity wall including sealing cavity to opening with slates in cement mortar</td>
<td>3/-</td>
<td></td>
<td>4:0</td>
</tr>
<tr>
<td>4 feet cube. Softwood in plates (3 in. x 2 in.)</td>
<td>19/8</td>
<td></td>
<td>18:8</td>
</tr>
<tr>
<td>10½ feet cube. Ditto in ground floor joists (4 in. x 2 in. and 4 in. x 1½ in.)</td>
<td>20/-</td>
<td>10:0</td>
<td>0</td>
</tr>
<tr>
<td>2 squares 75 feet sup. 1 in. (nominal) softwood tongued and grooved flooring and nailing to joists including cramping up and cleaning off</td>
<td>154/-</td>
<td>21:3</td>
<td>6</td>
</tr>
<tr>
<td>6 feet run. Extra for glued and mitred margin around hearths</td>
<td>7½d</td>
<td></td>
<td>3:9</td>
</tr>
<tr>
<td>6 feet run. 1 in. x ½ in. galvanised steel bar holed for and screwed to softwood floor and bedded in paving as stops</td>
<td>1/9</td>
<td>10:6</td>
<td></td>
</tr>
<tr>
<td>ADDITIONAL WORK in substructure for difference in floor levels between solid floor and sleeper joist floor constructions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 yards sup. Fine concrete filling to 2 in. wide cavity of hollow wall</td>
<td>3/10</td>
<td>11:6</td>
<td></td>
</tr>
<tr>
<td>1 yard sup. Reduced brickwork (9 in. thick) in Flettons in cement mortar (1:4)</td>
<td>32/-</td>
<td>1:12</td>
<td>0</td>
</tr>
<tr>
<td>1 yard sup. Half brick wall as last in ditto</td>
<td>16/4</td>
<td>16:4</td>
<td></td>
</tr>
<tr>
<td>3 yards sup. 11 in. hollow wall of two half brick thicknesses as last with 2 in. nominal cavity tied together with galvanised malleable iron twisted wall ties (No. 3 per yard super)</td>
<td>33/6</td>
<td>5:0:6</td>
<td></td>
</tr>
</tbody>
</table>
2 yards sup. Extra over half brick walls of hollow walls for sand faced Flettons and pointing as work proceeds 6/10 13 8

1 foot run. Labour, plumbing external angles in ditto 14d 2

TOTAL £74: 11: 9

**SOLID FLOOR REQUIRING SURFACE EXCAVATION.**

38 yards sup. Excavate vegetable soil, etc. average 6 in. deep remove and deposit all as Example 1 1/4 2: 10: 8

4 yards cube. Excavate to reduce to levels and get out 5/9 1: 3: 0

4 yards cube. Remove surplus excavated material not exceeding 100 yards run, spread and level on site 6/- 1: 4: 0

31 yards sup. Bed of hardcore blinded for concrete well consolidated to 5 in. (finished) thickness including levelling and ramming surface under 4/7 7: 2: 1

31 yards sup. Concrete (1:2 1/2:5 - 1/4 in mesh aggregate) bed 4 in. thick spread and levelled for paving on hardcore (measured separately) 6/11 10: 14: 5

5 feet run. Extra labour and mold forming sunk pipe chase 2 in. deep and not exceeding 6 in. wide on last including extra concrete under and make good for paving 1/3 6: 3

31 yards sup. 1 in. cement and sand (1:3) screed on concrete trowelled smooth and true for Thermoplastic Tile flooring 5/9 8: 18: 3
31 yards sup. ½ in. Thermoplastic Tile flooring and laying on concrete including bituminous mastic bedding P.C. 10/6 per yard super complete and add for profit, attendance, covering up and protect flooring  

<table>
<thead>
<tr>
<th></th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 4/₉</td>
<td>17</td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

6 feet run. 1 in. x ½ in. galvanized steel bar bedded in floated bed as stop between pavings  

<table>
<thead>
<tr>
<th></th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/₉</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL 350: 0: 4

**SUMMARY.**

Saving in cost per house ... ... £24:11:5d
Saving per yard super of flooring ... £ -15:10 ½d.
## ANALYSIS NO. 2.

**SUSPENDED TIMBER FLOOR.**

Quantities of labour and materials comprising a wood floor which are not common to a solid floor for a total area of 275 sq. ft. on a level site based on current rates of wages and cost of materials.  

24th February, 1954.

<table>
<thead>
<tr>
<th>Yds.</th>
<th>Ft.</th>
<th>s.</th>
<th>d.</th>
<th>£.</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 5</td>
<td>9&quot; x 3&quot; terra cotta air bricks and building into outer skin of hollow walls</td>
<td>2</td>
<td>9</td>
<td>13</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>No. 5</td>
<td>Hollow tile cavity ducts and building into inner skin of hollow wall and across cavity including slate lintol</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>No. 79</td>
<td>Common brick supports for floor joists including pad of 4½&quot; damp proof course and setting and bedding</td>
<td>5</td>
<td>1</td>
<td>12</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Sup</td>
<td>Horizontal damp proof course of fibre-base bitumen to B.S. 743 and laying on brickwork of chimney breast properly lapped at all joints and passings</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>7 run</td>
<td>Extra labour only on last item for dressing damp proof course down face of wall</td>
<td>½</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49 run</td>
<td>Damp proof course as item 5 laid across inner 4½&quot; skin of hollow wall and dressed down internal face of wall</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>32 run</td>
<td>Ditto 10½&quot; girth laid on top of 4½&quot; wall and dressed down 3&quot; on one face</td>
<td>11½</td>
<td>1</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Yds.</td>
<td>Ft.</td>
<td>s.</td>
<td>d.</td>
<td>£.</td>
<td>s.</td>
<td>d.</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>8 1/2</td>
<td>cube</td>
<td>Fir and all labour in ground floor joists (3&quot; x 2&quot;) carried on brick supports (measured separately)</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

| Sqs. | 2 | 67 | Sup | 1" (Nominal) deal tongued and grooved flooring in batten widths well cramped up, each board nailed to fir joists with and including all cutting and waste | 140 | 0 | 18 | 13 | 10 |

| 3 | Sup | Ditto in small quantities in door openings on and including fir bearers | 2 | 9 | 8 | 3 |

| 30 | Sup | 4" Extra depth of surface excavation | 9 | 1 | 2 | 6 |

| 2 | Sup | Extra half brick partition walls | 15 | 0 | 1 | 10 | 0 |

| 1/10 | Cube | Hardcore filling to fender walls | 22 | 6 | 2 | 3 |

**£35 7 6**
In the references made to the Italian and Spanish use of reinforced hollow block beams (Part One, Vol.2) it would seem evident that these prefabricated beams are bound to be less costly than any of the prefabricated flooring systems available in this country. The cost of the cheapest "in situ" suspended concrete floor probably works out at 32/- per sq. yd. and the cheapest precast slab floors available in this country are about 30/- per sq. yd. These figures are based on a clear span of 12 ft. and a normal superimposed loading for housing. Also the upper surfaces are considered to be left unscreeded.

Spanish or Italian costs for their particular types of flooring have not, at the moment of writing, become available. Detailed costs were promised at a meeting with architects in Barcelona, August 1956, but in spite of written reminders these details are not yet to hand. However, in the experiments with prefabricated block beams (described in Part One, Vol.2.) the cost of the material and the time taken for prefabrication was noted and the costs were estimated to be as follows:-

The 24 blocks used to make up the two beams, together with the cement-mortar for cross-jointing and fillets/
fillets and the reinforcement cost rather less than £3 £3. If hollow clay blocks of the right section had been available the cost would have been much less than this.

The time taken to prefabricate each of the two beams did not exceed ¾ hr., so one hour sufficed to prefabricate both beams, and if the advantage of repetition was taken into account then the time should be much less than this. Altogether, including overheads, etc., the cost for the two beams, built in clay blocks, should be approximately 1/- each block = 24/-, plus cement-mortar and reinforcement, say 28/- altogether. Add 6/- for time in manufacturing and say 2/- for placing, the total is 36/- for 24 sq. ft. of fixed beams, which is 1/6d. per sq. ft. or 13/6d. per sq. yd. To this must be added the cost of flushing up with cement-mortar for a lightly loaded roof similar to that shown or the cost of a properly designed concrete topping incorporating independently reinforced ribs.

Even in the latter case the cost per sq. yd. of unscreeded floor should not exceed 25/- per sq. yd.
Owing to the wide development in the U.S.S.R. of precast concrete components for large-scale house-building, the use of the "in situ" or monolithically cast concrete floor has largely been discontinued and instead, the Russians use either the light precast concrete beam with wet concrete topping or a large precast concrete multi-cellular floor panel. Generally the large precast floor panel finishes to a thickness of 4 in. against 6 in. for the "in situ" floor and the cost comparison for the two types of floor is stated to be to the advantage of the precast floor by about 50%.

The multi-cellular precast floor panels range from 1.5 to 5 tons in weight and are lifted into position by large capacity tower cranes. It is only since 1954 that such heavy components could be handled - for during the two years 1954 and 1955 there has been a gradual re-equipment of the U.S.S.R. building industry that has resulted in the introduction of the more powerful erecting cranes and a corresponding increase in the production of larger components in the factories.

In this country perhaps the only comparable example of precast concrete floor sections on housing work is in the Picton St. flats and it may not be possible to obtain accurate cost data on this project before the completion of this thesis.
Floor Finishes

The accelerated post-war development of a comprehensive range of floor finishing materials in exciting and varied colours was given its initial impetus by the familiar shortage of softwood immediately after the war finished and building began again. The thermoplastic floor tile was produced mainly to cover the solid concrete ground floors in post-war houses and at the present time it is remarkable that the total production of thermoplastic tiles in this country is second only to the production of linoleum. It seems that linoleum still holds the field as a quick and effective covering for solid or boarded floors and it is probably true to say that a large part of this production of linoleum is used on boarded floors in houses.

A good linoleum costs anything from 10/- a sq.yd. in a plain colour and it is not generally realised that it is possible to lay hardboard as a floor covering at less than this. I have experimented with this in new house construction and have laid ordinary good quality brown hardboard, 3/16ths. in. thick, supplied at less than 5d. per sq. ft. over softwood floors in sheets 8 ft. by 4 ft.

The manufacturers of hardboard have never recommended/
recommended the ordinary grades of hardboard for flooring purposes and have only just recently began to produce a hardboard with a specially hardened surface which is intended for floor coverings. This material is 1/8th in. thick and is made in several colours at approximately 10d. per sq.ft. This is quite a substantial increase on the cost of ordinary quality hardboard and tends to defeat the economic advantages of its use when compared with the price of linoleum or of thermoplastic tiles at about 1/2d. per sq.ft. From my own experiments and observation of the behaviour of ordinary quality hardboard on floors where normal wear has taken place over more than two years it appears evident that the ordinary standard quality board, provided it is kept well waxed with polish, is quite as resistant to wear as good quality linoleum.

Hardboard can be fixed to boarded floors by widely spaced panel pins or it can be fixed by special adhesives to a solid concrete floor. It joints up very closely, can be turned or patched neatly if and when wear occurs, and it takes a high polish. Since the standard sizes of sheets are 8 ft. by 4 ft. there is an opportunity here to benefit from modular coordination with such a floor covering that can be put down quickly with a minimum of cutting and a minimum wastage of material.
ROOFS.

The section on roofs in Part One included a short reference to the trussed rafter structure favoured by many of the larger Scottish firms. The economies realised by these trusses in place of the usual massive roof construction peculiar to Scottish building must be quite substantial bearing in mind that timber for roofing purposes costs over £100 a standard. American research comparing trussed timber roof construction with conventional construction has indicated that there is a saving of about 30% over the manhours required in the conventional construction and the saving in softwood was approximately 40%. The Americans seem to use the plywood gusset plates more than Scottish builders and extremely high strength values for these joints have been obtained by utilising the full strength of nails in double shear by using extra-long nails and clinching the ends over.

The efficient use of modern nailing methods and of timber connectors has improved productivity and modern synthetic resins are becoming an important supplementary to the first mentioned methods. Timber trusses can often replace steel trusses and show substantial savings in cost, for/
are for timber trusses/comparatively light and consequently less expensive to transport and erect. Usually there is no need for mechanical equipment to lift the trusses into position for quite a large timber truss can be lifted by four men.

Details of the cost of timber trusses with glued joints were given in a recent report by the Civil Engineering Department, King's College, Newcastle-upon-Tyne and were as follows:

Nine large trusses for the Ante-Natal Clinic, Princess Mary Hospital, Newcastle, required 177 cu.ft. of timber at £306 with £161 added for steel fittings.

Eighteen north-light trusses for a boat house at the University, Durham, required 90 cu.ft. at a cost of £140. It was estimated that the cost would have been £300 if steel trusses had been used.

Thirty-two large lattice beams at Marske School, N.Riding, varying in size, the largest bridging a roof span of 42ft. 9in. All 32 beams for £679.

It was also stated in the report that a local builder using glued timber trusses up to 80 ft. span had claimed to have cut his roofing costs by half, attributing a large part of this saving to ease of handling on the site and convenience of production in prefabricated units, half-units, or less in his own joinery shop.
The prefabricated roof truss is used by Messrs Tarran & Son in their mass produced house which is manufactured in a Perth factory. The roof is made up in two half-trusses, side by side at fixed centres, fastened and braced together by the actual sarking and tiling lath, so that practically all the roof construction except the tiles is completed before leaving the factory, and of course the tie beam of each truss serves as a pre-fixed ceiling beam.

These twin half sections are carried by six men up a specially prepared ramp to first floor level from which they are raised on to the wall plate and anchored to it by metal clips. The system of erection of the entire house is most economical in site labour - particularly so in the matter of skilled site labour. A team of two joiners and twelve labourers erect a pair of houses in one day; then twelve joiners, one plumber and mate and one electrician complete the finishings of four houses per week ready for painting.

The technique of making up pairs of trusses with sarking and tile lath already fixed is particularly economic of site manhours and it is very likely that some savings in material costs might be realised in using up short ends and narrow sarking widths.
In Vol. 2 of Part 1 the arguments in favour of the mono-pitched roof were put forward, particularly for the economic roofing of terraced type two and three storey houses as distinct from tall blocks of flats. It has not been possible to support these arguments with actual cost data from recently completed housing schemes, generally because the few authorities in Scotland that have used this type of roof have not made elemental analyses available.

From cost analyses of flat roofs on school buildings the elemental cost per sq. ft. taken over an average of three primary schools is 5/6d. for 6in. R.C. slabs 12in. wide, 25 ft. span, 4 in. by 1 ft. 9 in. R.C. channel gutters, 3 in. foamed slag screed and two layers of built-up felt roofing. Reference to the cost analyses at the end of this volume will show that the average elemental cost of traditional pitched roofing is about 2/6d. per sq. ft. This comparison is valueless, for apart from the fact that it does not support the case for the flat or mono-pitched roof the building types are different. For example the classroom requirement of 25 ft. clear span does not operate in house design and it should be possible to keep the spans to 12 or 14 ft. or so. The construction could then/

* Some interesting cost data have since been obtained on mono-pitch and low-pitch roofing at Glenrothes New Town, Fife. (See following pages)
then be based on a system of wood joists supporting wood-wool slabs or strawboard covered with a bituminous built-up felt roof covering. The wood-wool slabs or strawboard constitute the most expensive item in the roof but it is likely that the cost of these materials will reduce in the future as greater quantities are manufactured. In any case the insulating qualities of these materials as compared with the standard roof coverings cannot be disregarded.

In a recent survey of 72 blocks of multi-storey flats over a wide area it was noted that only four out of the 72 blocks had pitched roofs. This suggests that the flat roof has been accepted as the most suitable type of roof for high blocks of flats and indeed this must be so since most of these buildings have framed construction and it is much more simple to design a flat roof more or less as a repetition of a floor than to cover the building with a pitched roof. In a report on this B.R.S. survey of 72 blocks of tall houses Mr. C.N. Craig commented on the unsuitability of flat roofs, basing his criticism on the fact that the necessity for lift motor rooms, extensive tank rooms, etc., presented the architect with the problem of designing odd looking roof buildings. Craig went on to suggest that we/
we might follow the example of certain designers of high blocks on the Continent who had provided a pitched roof which had a lower first cost, a longer life and allowed space for tanks, pipe runs and motor rooms.

Although I feel that pitched roofs may often be more suitable than any other form of roof for certain buildings up to three storeys in height I cannot follow the argument that a pitched roof is an economic proposition for a high block of flats. The two photographs (above) that I took of low-cost house-building in Milan surely indicate that the Continental pitched roof construction is extremely costly. The picture on the left also shows that it is still necessary to build separate roof buildings for tank and motor rooms.
At the new town of Glenrothes, Fife, several types of roof forms have been used and include traditional pitched construction, low-pitched and mono-pitched. The following cost data for these roofs are set out below and make quite an interesting comparison:

**Traditional Type Roof construction**

Floor area - 877 sq.ft.

Roof Slope area - 74 sq.yds.

**Price Data.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Unit</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&quot;x1&quot;</td>
<td>Sawn wallplate</td>
<td>Lin.Ft.</td>
<td>4½d.</td>
</tr>
<tr>
<td>5&quot;x2&quot;</td>
<td>Sawn ceiling joists</td>
<td>&quot;</td>
<td>1/1½d.</td>
</tr>
<tr>
<td>5&quot;x2&quot;</td>
<td>Sawn spars</td>
<td>&quot;</td>
<td>1/1½d.</td>
</tr>
<tr>
<td>7&quot;x1&quot;</td>
<td>Ridge</td>
<td>&quot;</td>
<td>9½d.</td>
</tr>
<tr>
<td>4&quot;x1½&quot;</td>
<td>Struts and collars</td>
<td>&quot;</td>
<td>10d.</td>
</tr>
<tr>
<td>½&quot;</td>
<td>Insulation boarding</td>
<td>Sq.yd.</td>
<td>5/3d.</td>
</tr>
<tr>
<td>10&quot;</td>
<td>Sarking</td>
<td>&quot;</td>
<td>8/6d.</td>
</tr>
<tr>
<td></td>
<td>Slating felt</td>
<td>&quot;</td>
<td>1/0d.</td>
</tr>
<tr>
<td></td>
<td>Tiling battens at 12&quot; centres for 15&quot;x9&quot; concrete interlocking tiles</td>
<td>Sq.yd.</td>
<td>1/6d.</td>
</tr>
<tr>
<td></td>
<td>Tiling battens at 4&quot; centres for 10½&quot;x6½&quot;plain concrete roofing tiles</td>
<td>Sq.yd.</td>
<td>3/3d.</td>
</tr>
</tbody>
</table>
15"x9" Concrete interlocking tiles (including labours), e.g. Alloa Dark Red Tiles. Sq.yd. 9/3d.

10\frac{1}{2}"x6\frac{1}{2}" Concrete plain tiles (including labours) e.g. Hawkins Dark Heather Burlington Peggie Slates (including labours) " 15/2d. 20/6d.

Cost per sq.yd. (of roof slope) of typical traditional type roof inclusive of ceiling joists, spars collars, baulks, etc., insulation boarding, but exclusive of ceiling finish and tile or slate finish to roof. Sq.yd. £1:5:9d.

Do. do. do. with 5/8" sarking on the roof. £1:9:0.

Low Pitch Type Roof /
Low Pitch Type Roof.

Floor area - 872 sq.ft.
Roof slope area - 64 sq.yds.

Price Data.

4"x3" Sawn wallplate Lin. ft. 1/2d.
7"x2" Rafters " 1/7d.
5"x2" Skew board " 1/1½d.
2½" Gyplith woodwool slabs Sq. yd. 11/6d.
½" Sand and cement screed on top of Gyplith " 3/6d.
Three layers mineral surfaced bituminous felt roofing. (including labours) " 10/0d.

Cost per sq.yd. (of roof slope) exclusive of ceiling finishes and of screed and bituminous felt roofing on roof. Sq.yd. £1:3:5.

Mono-Pitch Type Roof.

Floor area - 769 sq.ft.
Roof slope area - 69 sq.yds.

Price Data/
Price Data.

All the same as for the low-pitch roof.

Cost per sq.yd. (of roof slope) exclusive of ceiling finishes and of screed and bituminous felt roofing on roof. £1:4:8.

---

<table>
<thead>
<tr>
<th>Description</th>
<th>Traditional Pitch</th>
<th>Low-pitch</th>
<th>Mono-pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>£1:5:9</td>
<td>£1:3:5</td>
<td>£1:4:8</td>
</tr>
<tr>
<td>Slating felt</td>
<td>1:0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tiling battens for 15&quot;x9&quot; concrete interlocking tiles</td>
<td>1:6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>15&quot;x9&quot; concrete tiles (including labours)</td>
<td>9:8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>½&quot; sand and cement screed</td>
<td>-</td>
<td>3:6</td>
<td>3:6</td>
</tr>
<tr>
<td>3 layers mineral surfaced bituminous felt roofing</td>
<td>-</td>
<td>10:0</td>
<td>10:0</td>
</tr>
</tbody>
</table>

£1:17:11 £1:16:11 £1:18:2

These cost data are for a large contract and though not representing 1957 figures they are of the same date and are/
are therefore comparable. They show that there is little difference in the cost of the respective roofs and according to the figures for roof slope area the traditional type roof contains only five more sq.yds. of area than the mono-pitch roof. But the plan shapes of the houses differ considerably from each other, and the mono-pitch roof overhangs 2 ft.6 in. at the eaves on the high side and at least 1 ft. everywhere else, while the traditional roof has an eaves overhang of only three or four inches.

A level ceiling has been provided under the mono-pitch roof, taking up additional timber and labour simply to obtain the conventional form of ceiling. In my view this was unnecessary, for the small amount of roof space obtained was far too shallow to be of any use for the housing of storage tanks, etc. Indeed, as I have pointed out in Vol.2 of Part I there ought not to be any great objection to exposed beams in the bedroom ceilings of low-cost houses, provided they are well positioned and as widely spaced as possible.

In the house plan to the mono-pitch roofed house it was interesting to see that the architect had taken full advantage of the adaptability of this kind of roof to/
to odd-shaped or irregular wall outlines, for in this instance the plan was by no means simple and included four square angled and three obtuse angled breaks in the plan outline. Quite obviously it would have cost a great deal to roof in such a building with a traditional style roof and for this type of housing such a plan form would have been impracticable.

It is unfortunate that it was not possible to make a more suitable comparison, say between exactly similar types of house plans, but with different roof construction. This might well be possible in England but in S.E. Scotland the field is limited, in fact these houses in the New Town at Glenrothes represent the first mono-pitch roofs to be featured on housing schemes in this area.

However, the cost data have shown that there is little difference in the cost per sq.yd. measured on the slope and it needs only a simple calculation to prove that an overall roof-span of, say, 21 ft. can be covered by a mono-pitch roof, slope 5 to 10 degrees, with a rafter length of 23 to 24 ft. Compare this against a traditional type roof, 35 degrees slope, supporting concrete tiles over the same span and the total rafter length comes out at 27 to 28 ft. In other words the mono-pitch roof is 17% less in area for the same coverage of plan area.
An interesting method of cost-saving by the introduction of a mono-pitched roof on week-end villa near Palamos, Costa Brava, Spain.

Mono-pitched roof on low-cost rural housing in N.E. France.
An interesting method of cost-saving by the introduction of a precast concrete rhone or gutter block in the place of the normal eaves construction has been used to a considerable extent in Scotland under the patentee's name of Finlock Gutter. The photograph shows a pile of these blocks in the yard of a Scottish distributor.

The blocks take the place of the traditional Scottish wallhead and rhone, and for this reason they have rather a special application to house-construction as practised in Scotland. Bedded and jointed at the top of the wall they close the cavity and present a neat eaves overhang, furthermore they can be reinforced and concreted "in situ" in such a way that they act as lintols over openings. The economies claimed for these blocks derive from saving in certain courses of walling at the wallhead, the elimination of the timber normally required to form an overhanging eaves, certain reductions in the amount of roof covering at the eaves and gutter brackets together with/
with the cast iron rhone itself. The capacity of the bowl of the gutter can be seen from the photograph to be far greater than ordinary cast-iron rhone and as a consequence of this the number of downpipes or conductors can be reduced. Then there is the long-term saving on painting and maintenance of a metallic gutter.

The following summary is of figures based on an the construction of a pair of houses equipped with this form of eaves construction:

<table>
<thead>
<tr>
<th>Omissions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Briclayer's work</td>
<td>£15.17.0</td>
</tr>
<tr>
<td>Carpenter's</td>
<td>£25.10.10</td>
</tr>
<tr>
<td>Tiler's</td>
<td>£9.18.0</td>
</tr>
<tr>
<td>Plumber's</td>
<td>£25.11.0</td>
</tr>
<tr>
<td>Painter's</td>
<td>£3.7.6</td>
</tr>
</tbody>
</table>

Total saving £80.4.4.

Additions 137ft.4 in. of patent precast concrete gutter delivered, fixed and lined £63.1.4.

Total saving £17.3.0.

Further savings were reported in the same houses due to the use of the blocks as lintols and to the reduction of the number of conductors from the rainwater outlets.
Plumbing Installations.

The elemental cost analyses at the end of this Volume have indicated that the plumbing installation in the average low-cost house costs approximately 5/- per sq. ft. out of a total cost of 30/- per sq.ft. This represents quite a sizable proportion of the total cost and from what has been said about conventional plumbing methods in this country it is evident that there is scope for economy in materials and manhours.

Much has been written about the single-stack system advocated by the Building Research Station and there can be no doubt whatever that money could be saved in quite substantial amounts if only those responsible for this ridiculous adherence to traditional methods could be made to realise that scarce materials and manpower are being wasted in totally unnecessary piping, festooning over wall surfaces - an eyesore to everyone except the plumber.

Consider the photographs on the next page, taken on a "no-fines" site on the outskirts of Edinburgh in May 1956, nearly three years after the publication by the B.R.S. of the results of most comprehensive investigations and tests, directed towards the establishment of cost-saving data/
External plumbing work in progress on a "no-fines" concrete housing site at Liberton, Edinburgh.

The "Single Stack" system is adopted.

Conventional "Two-pipe" external plumbing installation on traditional brick houses at Liberton, Edinburgh.
data which has been available to architects, builders and plumbers through every medium of publicity from B.R.S. fourpenny Digests to sound films.

The first photograph shows that the architect has indeed seen to it that the method of single-stack plumbing is adopted, the four inch combined soil and waste pipe is there and ready for the bath and basin waste to be connected to it. But what seems most incredible is that the opportunity has not been taken to combine the wastes of the two houses in the one four inch single stack. This is supposed to be low-cost housing and it is being subsidised out of public money, yet here is a glaring instance of the waste of something like £7 to £11 of materials and labour, simply to give each house a separate stack-pipe.

The only excuse that could be offered for this extravagance is that each householder can be held responsible for any blockage arising in the stack, otherwise if the stack were common to both houses a careful tenant would have to put up with any nuisance arising out of a careless neighbour's use of the sanitary fitments. Clearly, such an excuse cannot reasonably be sustained, for the fundamental principle/
principle of building two or more houses together, with common walls or floors and ceilings, is surely to build more cheaply - otherwise we should all (if we could afford it) live in completely detached houses. In this particular instance the drainage from two houses has got to come together in a common pipe when it disappears below ground level so why not let the two houses drain into a mutual pipe for the few yards above ground? thus improving the appearance of the houses and cutting costs.

The second photograph is of traditional brick houses adjoining the no-fines site. Here we have the Scottish interpretation of the "two-pipe" system - a classic example of a plumbing method that has in the past caused the absolutely unnecessary expenditure of thousands of pounds of private and public money in Scotland - and as can be seen in this photograph - it is still going on.

In the two houses shown in the photograph are seen four pipes, two 4 in. soil pipes and two 2½in. or 3in. waste pipes. All are fully vented, and so is every other pipe all the way down the terrace of houses. The first point of criticism concerns the individual venting of the soil.

* The possibility of combining the two single stacks was put to the House Drainage Dept. Edinburgh Corporation. Reference to this is made in the following pages.
soil pipes, for surely it is not necessary for every soil pipe to terminate in a vent involving almost two additional lengths of pipe and a special bend. One vent pipe at the head of a length of drain serving a minimum of six houses would give complete efficiency of drain ventilation; many English authorities permit one four inch vent pipe to serve many more than six houses. I have frequently seen as many as 14 houses drains ventilated efficiently by one vent in housing schemes in the Midlands and in the South of England. So it is evident that unnecessary expense is being incurred on these Edinburgh Council houses.

The second point of criticism, and one which would appear to be indefensible, concerns the venting to the waste pipes shown in the photograph. At the feet of the two waste pipes there is, in accordance with Scottish practice, an underground fireclay trap which serves to disconnect the soapy waste pipes from the soil drain by means of the water seal in the trap. It follows then that there is no possibility of the waste pipe vents ventilating anything other than the waste pipe itself! It seems fantastic that all this unnecessary piping has been required by local authorities for so many years and is, apparently, still being/
required, both on private and local authority work.

It is understandable that building by-laws of many authorities are still tied up with the old Police Acts and still apply these absurd conditions to modern building work. But it is not necessary for local authorities to apply these conditions so rigidly when more appropriate building regulations - the Dept. of Health's Model By-laws - are available for adoption.

One final criticism of the arrangement of pipes shown in the lower photograph of the houses at Liberton. The two waste pipes could quite easily have been combined for they are only a few inches away from each other, and if the fitments inside the bathrooms had been re-arranged the entire group of four pipes could have been combined in a single, economic stack.

Reference has been made in Vol.2 of Part 1 to the Scottish requirement for a tub in addition to a sink in the kitchens of all houses, new or revised. It is not proposed to summarise the arguments, for or against the requirement, except to state simply that the extra fitment means about £10 or £12 additional cost.

* Scottish Burgh Police Acts.
The Chief Inspector in the Edinburgh Corporation House Drainage Dept. was asked why the two single stacks could not be grouped in the one pipe. His answer was that it was impossible to accommodate all the necessary branches in the one pipe without the use of special multi-branch castings that would need to be purpose-made and consequently very expensive, he added that the authority he represented would not allow branches in a multi-branch fitting to be sited opposite one another. This meant of course that special cast iron fittings with staggered branches would be required, and in the end the grouping of the external piping to the two houses within one pipe would prove to be more costly than the original system using the two pipes with standard cast iron branches.

The question was then put to the Chief Inspector why a multi-branch fitting with the smaller bossed outlets could not be used instead of a special cast iron fitting. The bossed outlets take up less room in a multi-branch fitting and it would perhaps be possible to obtain such a fitting with staggered branches to meet the local authority's requirements. But the reply to this question was that it would make no difference from the cost-saving point of view because copper piping would then be necessary for the branches and this would bring the ultimate cost to a level somewhat higher than that of the double pipe with cast iron branches.
In a report prepared by the Division of Productivity and Technological Developments of the United States Department of Labor's Bureau of Labor Statistics, published in December 1954 the result of a work study on the installation of a plumbing system in a six-room house was published. The house was typical of the average house erected by the particular firm and an average-sized estate of some fifty houses was selected for observation.

For this size of job, seven plumbers including a foreman were organised into three teams of two men each, the foreman controlling each team on a rotational basis, checking operations, ordering and keeping materials in constant supply, maintaining records and doing odd jobs. In order to determine the number of manhours required for such a project of 50 houses the foreman and an assistant actually carry out a "practice run". That is to say they do all the work in a complete installation and keep a detailed list of materials, manhours, operations, etc., to serve as a basis for a planned sequence of operations on the complete scheme. From his experience of the "practice run" the foreman works out improvements, short cuts, and in particular, he determines the amount of plumbing work that can be pre-assembled or prefabricated.
The prefabricated work is put in hand as soon as possible and the plumbing installation for the entire project is carefully planned so that the three teams, each of two plumbers can work efficiently without being held up for materials or other trades.

The use of prefabricated cast-iron stacks or "trees" was found to yield significant savings in manhours for it was established that the two plumbers could fix the cast iron piping to three houses in one day, whereas by conventional methods involving individual cutting, measurement and installation it took two plumbers one day to fix the cast iron work in one house. It was also shown that, using prefabricated galvanised-iron piping, two men could achieve at least 30% increase of productivity over two men using conventional methods.

These data were a little inconclusive because the manhours used offsite in the prefabrication of the cast-iron and galvanised-iron assemblies were not broken down sufficiently to set against the figures already mentioned. In the report it was simply stated that eight men, consisting of four mechanics and three apprentices could prefabricate both cast-iron and galvanised-iron installations at the rate of 125 houses per month.
In America, plumbing "packages" as they are called, are beginning to be accepted by most large house-building firms as a normal component of the modern house. Some resistance has been encountered from local plumbers in the areas where the prefabricated plumbing panels are installed. One reason advanced for the small plumber's antagonism is that in addition to a reduction of site work that would otherwise have been his, he loses the trade discount that he makes on the materials.

Mass purchase of materials and fitments enables the manufacturer of prefabricated plumbing "packages" to sell his finished article at a low figure, and savings to American builders are reported to vary from $75 to $300 per house. To quote one example, the Precision Built Homes Co. make up a plumbing "tree" which is installed in a six inch panel and connects to the various kitchen and bathroom fixtures. The cost to the builder for this completely prefabricated plumbing package, including fixtures is, for a one-bath house, approximately $400 and it is reckoned that the builder saves up to $200 per house compared with the cost of conventional plumbing, installed locally.

This/
This figure of $400 for a complete panel together with bath, sink and washbasin seems to be very low, even when the additional cost of installation is considered. The cost of a one-bath house in America is about $10,000, therefore the cost of the plumbing package represents only 4% of the total cost of the house. Even supposing the installation of the panel plus all other external plumbing such as rainwater disposal, flashings, etc. cost say $600, making the total cost of the plumbing $1,000; this would only be 10% of the all-in cost of the house, against the figure of 13% or 14% indicated in the cost analyses on Scottish low-cost housing.

Some references to the use of prefabricated plumbing panels in a most recently built block of experimental flats in Milan were made in Vol.2 of Part I and photographs are shown on the next page, giving some idea of the scale of the prefabrication. Unfortunately, Prof. Ciribini was unable to give precise comparisons of the cost of the prefabricated panels with that of ordinary plumbing work, though he was quite satisfied that the experiment had been fully justified by such cost data as he had been able to assemble at that early stage of erection.
Prefabricated Plumbing Panels in Flats at Milan

Unloading the Panels on the Site.
Standardisation and prefabrication can do much to increase productivity in plumbing systems on housing work. Much has been accomplished since the war in formulating British Standards for plumbing materials, but unfortunately there are many Water Authorities who still show reluctance towards adopting certain of the Standards in full. For example, B.S.1010 specifying the design of stopcocks has not yet been universally adopted in this country - so there is still the unnecessary and wasteful situation where manufacturers are having to make different types of stopcocks to conform to the particular wish (or whim) of the local Water Authority.

Prefabricated plumbing, as described in Vol.2 of Part One, should ultimately become an accepted component of all but the most individual and exclusive "one off" houses. The critics of prefabricated plumbing have argued that once a unit becomes too large the costs of transport and handling mounts rapidly until prefabrication becomes uneconomic. This is probably a sound argument so far as the large systems such as the French " Bloc Technic " are concerned.

But/
But prefabricated panels similar to those installed in the experimental flats at Milan (photograph on preceding page) raise no special problem of transport or handling.

From what has been said in Vol.2 of Part One and in this summary it is quite clear that plumbing costs in most of the new houses could be effectively reduced if house plans were based on a module and the relationship between the various sanitary fitments reduced to a minimum number of combinations, thus making it possible to standardise piping systems within a reasonably narrow range of house-types. At the same time it is essential that the Scottish local authorities should cooperate with the designers who strive to reduce housing costs through simplification and prefabrication.

It is encouraging to note that Edinburgh Corporation has adopted the "single-stack" system of plumbing in three hundred new houses at Muirhouse and has also been responsible for asking the Scottish Convention for Royal Burghs to recommend the system to all local authorities in Scotland. Nevertheless these signs of a more tolerant and progressive attitude to techniques which have been tried and proved so long ago are most tardy. A number of English local authorities have been saving £14 to £20 per house with this system since 1952.
Plastic Piping.

Since reference was made to this new material in Part One (Vol.1), Imperial Chemical Industries have now started to make small quantities of a higher density grade of polythene sheet and it will be called Alkathene H.D. This material is slightly heavier and considerably stiffer than the standard Alkathene and it has been found to withstand a much higher temperature before softening and changing form. This property of increased resistance to heat may make it possible to manufacture a plastic pipe that can be used in hot-water services.

Other technical developments directed towards producing a plastic pipe that will carry hot water satisfactorily are taking place. In a report on substitution prepared by a special committee of the International Wrought Non-Ferrous Metals Council it was mentioned that aluminium-sheathed plastic tubing might soon be available and would be capable of containing hot water without failure.

These developments taken together with evidence of an increasing use of plastic piping for cold water services in buildings all over the world suggest that we may/
may see an extensive switchover to the use of plastic piping instead of copper.

In a survey made by the British Plastics Federation shortly after the severe winter of 55-56 it appeared that polythene cold-water piping escaped damage from frost in all cases. For example, in Birmingham there were 3,600 bursts in ordinary piping installed in Council property and none in the plastic pipe installations. Of course the survey did not mention how many houses in Birmingham had been fitted with plastic piping compared with the others but generally, from other figures quoted it would seem fairly safe to say that maintenance charges on house property during this cold spell would have been substantially lowered if plastic piping had been used in all cold water services.

From the point of view of cost-saving the manufacturers of plastic pipe in this country are a little reticent on the comparison of the cost of polythene against conventional methods of cold water services. They tend to rely on the long term advantages of freedom from damage caused by frost or corrosion rather than any short term/
term or initial saving in cost.

One drawback at the moment is that the I.C.I. fittings for plastic pipes all have to be one size larger than the pipe diameter and this increases the cost. But I am assured by I.C.I.'s representative that research and experiment is going on and it is certain that very soon a new type of fitting will be produced commercially that will get over the disadvantage mentioned. *

The Scottish Special Housing Association has used plastic piping for cold water supply in many of their housing schemes and the Chief Surveyor has estimated that a consequent saving of about £2 a house has been secured. It is also significant that the S.S.H.A. now make the use of plastic piping optional in most of their schedules.

There is little doubt that plastic piping will compete more strongly with conventional forms of piping as soon as it is possible to use it for hot and cold services, The City Architect of Edinburgh has told the I.C.I. representative to keep away until he can supply the plastic pipe for hot and cold services. It is evident that there are many other architects of the same mind.

* see next page.
Towards the end of 1956 the section of the Imperial Chemical Industries Ltd. responsible for research concerning plastic pipe development announced that a satisfactory plastic fitting had been produced. The fitting is available as a straight or a bent coupling and has the function of connecting successive lengths of plastic piping.

This photograph shows two short lengths of plastic pipe joined together by a straight coupling. A spare coupling is seen by the connected lengths of pipe.

The new connection is small and neat in appearance and it is made of exactly the same kind of material as the pipe. The method of forming a watertight joint is simple; a short bent piece of wire is embedded in the plastic connection so that the wire encircles the connection and its two free ends are exposed. This wire is of course an integral component of the connection and is inserted during the manufacture of the coupling.
coupling.

When the coupling has been slipped over the ends of the pipes to be joined, a six-volt low tension battery is connected to the free ends of the wire embedded in the coupling. The shorting of the current passing through the wire causes heat which fuses the coupling to the pipe. The action is very similar to that in the making of a joint between copper piping and a capillary fitting, where heat is applied by means of a blow-torch and hot solder is assisted by capillarity to run through and fill up the tiny space between connection and piping.

It is quite obvious that this new connection can be mass-produced at low cost, for it is so simple in design and nothing more than plastic material and wire is needed. But because the I.C.I. also manufactures metal couplings for plastic piping the present policy of the Company is to keep the price of the new fitting level with the price of the more elaborate and costly metal fitting, in order that the one product of the firm shall not be in competition with the other! So we have the Gilbertian situation where painstaking and clever research has produced a fitting that could sell profitably at about 8d, but which must be sold at approximately 3/6d!

The Electricians' Trade Union representatives have claimed that these joints should be made by electricians!
A Prefabricated Plumbing Panel of Plastic Piping in Experimental Flats at Milan.

Professor Ciribini is trying out a few of these panels in plastic piping carrying hot and cold water supplies and also hot wastes from the sanitary fitments. It has been necessary to provide special support for certain of the piping carrying hot liquids - this can be seen in the picture.
At the moment, plastic materials have comparatively little to do with low-cost housing except in the way of small components like door handles, electric fittings, lavatory seats, etc., but I feel that in this new material there is a unique opportunity for the building industry to develop completely new constructional techniques by adopting completely new and exciting principles of design.

One cannot help but wonder whether or not it is worth while designing houses to last for a hundred or more years. There are not many 100 year old houses today that are comfortable to live in according to present standards, unless they have been substantially altered to permit proper heating, plumbing or daylighting. Is it then likely that the new houses of this technical age will be obsolescent in 50 years or so? If this is so then one can understand why it should be necessary for manufacturers and designers to re-examine the whole concept of the need for permanence in buildings and building components.

In fifty years time or less, may we not see the houses in the form of a reinforced plastic Geodesic structure, made up of opaque, translucent and transparent panels, with floors of modular panels of foamed plastic cores and stressed skin surfaces?
Domestic Heating.

The common wastage of valuable room space in houses by unnecessary or excessively large chimney breast projections has been criticised under "Fireplaces and Flues" in Part One. If approximately 4% of the floor space in a room can be saved by the omission of an unnecessary fireplace the saving could be of the order of £1.10.0 to £2 per sq. ft. or £6 to £8 for each instance where the chimney breast is cut out. This is reckoned on the rough basis of £1,500 to £2,000 for a small house.

The question of the adoption of the slow-burning closed type of stoves for general use in domestic interiors is bound up with the very difficult problem of revising existing building byelaws so that the full range of economics resulting from the closed stove form of heating can be realised. There is a need for a more realistic approach in by-laws to the provision of a sufficient flue for a closed stove - at the present time the latest Dept. of Health Model By-laws require the flue to be surrounded by incombustible material, at least four inches thick. This requirement is surely a little excessive in the light of Continental experience of the fire hazards of these slow burning/appliances.
burning appliances.

The provision of a 4 in. thickness of material around a chimney flue restricts any possibility of housing flues within, say, a mutual or party wall and a wasteful projection of some kind is usually inescapable.

The Dept. of Health Model By-laws appear to dispense with the old requirement for proper jambs surrounding a free-standing appliance and there is a very limited concession concerning the connection of two appliances to one flue. But there is an unfortunate vagueness in the matter of domestic flue sizes which is likely to permit local authorities to exercise their own broad interpretation of what is a minimum size for domestic appliances. And it is more than likely that most authorities will continue to enforce the traditional minimum of the 9 in. x 9 in. flue.

The answer of the local authority to this criticism is understandable - obviously the by-laws in this country have to take account of the possibility that new occupants of property may not like the appliances provided for the former occupants and may install conventional open fires in their place. The ordinary open fire does indeed require a large flue outlet to cope with the gases produced by inefficient/
inefficient combustion and any doubling up or branching of flues as suggested in Part One may have disastrous consequences.

This leads one to the question "why can the Dutch, French, Italians, etc. build multi-storey houses with branched flues, so much smaller than the minimum flue sizes prescribed in our own building regulations?" The answer is that solid fuel is so much more scarce and expensive than in this country where a Nationalised Coal industry produces coal, supplemented by imports from Belgium and other countries, and sells it to the consumer at a price that is kept to an artificial level by subsidies. If the domestic consumer had to pay a price for his fuel, comparable with that which the Continental pays, then it is more than likely that this country would see far more adherents to the closed stove than hitherto.

It has been stated that air pollution is costing the country £250 million a year in direct costs and loss of efficiency. This is equivalent to £10 per head of population in the "black areas" of Britain and of £5 per head throughout the whole country. When these notes were written the Government's Clean Air Bill had gone to the House/
House of Lords. The Bill was described by the Director of the National Smoke Abatement Society as "as good a measure as we can expect to get at the present stage of public opinion" and there is no doubt that there are very many people who still have little or no interest in the matter of clean air.

However, the passing of this Bill and the future creation of more smokeless zones throughout the country are bound to combine with the high price of solid fuel in effecting a change of outlook towards the efficient use of domestic fuel in the closed stove as opposed to the wasteful open fire. If this happens, then it is probable that we may see some changes in the conventional forms of fireplace openings, flues and chimneys, changes that will dispense with much of the unnecessary weight of foundations and supporting walls and much of the wastage of valuable space so frequently caused by fireplace openings, jambs, chimneys and flues. We may see, in the not too distant future, the adoption of the Continental system of free-standing appliances, owned by the tenant as a "tenant's fixture", communicating with a flue-block set flush in the wall, similar to a gas fire.
District heating scheme at Bonnyrigg, Nr. Edinburgh. This photograph shows the central heating plant at the left hand side of the picture. The plant consists of large mechanically fed boilers, thermostatically controlled, supplying low-pressure hot water to heating pipes and domestic supply. This scheme is applied to several hundred houses of different types including three-storey flats and semi-detached houses. Heating goes off from June 1st to October 1st, but domestic hot water supply continues. The all-in weekly charge throughout the year is 12/6d. and it is just paying its way after running for the initial three years at a loss.

Although this is hardly a constructional technique there are secondary savings effected through the omission of fireplaces and flues; the pictures emphasise the oddness of houses without chimneys.
Electrical Installations.

The installation of a ring main electrical service in the average small American house can take as little time as 29 manhours when the work is carefully organised as a progressive operation. In a case study analysing operational and manhour requirements for the installation of an electrical system in a typical five-room, one-family house, the work was broken down into the four operations listed in the table below:

Operations Analysis and Man-hour Requirements for Installation of Electrical System.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Description</th>
<th>Man-hour Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1.</td>
<td>Installing cable run, switch boxes, etc.</td>
<td>12</td>
</tr>
<tr>
<td>No. 2.</td>
<td>Meter board, fuses, fuse-boxes. Installation of switches, plugs, etc.</td>
<td>10</td>
</tr>
<tr>
<td>No. 3.</td>
<td>Lighting fixtures, pendants.</td>
<td>3</td>
</tr>
<tr>
<td>No. 4.</td>
<td>Oil burner heating point.</td>
<td>4</td>
</tr>
</tbody>
</table>

Total manhours for complete electrical installation. 29

This total of 29 manhours for a complete installation including the four hours on the oil burner, which is hardly a normal item of service in British installations shows that job specialisation can improve productivity.
Mechanisation

The application of mechanisation to many processes in building work has been mentioned in the various sections of Vol. 2 of Part One and it has been shown that there is a great field here for speeding processes or for reducing labour expenditure. Machines are available that may be used in builders' yards or may be taken on to the site and used at the actual point of construction.

It is no longer possible for the contractor to plead that the plant is not available, though he may argue that the present restriction of credit facilities prevents him from buying or hiring the machines. In this connection it is interesting to note the scheme which is operated by the Eastern Federation of Master Builders in England, by which a pool of mechanical building equipment is made available to all members of the Federation.

All building jobs, large or small, may be mechanised to a greater or lesser degree and will show a saving as a result of that mechanisation - so long as the machines are mobile and reasonably cheap, and the work is carefully organised to ensure an economic sequence of work for every machine.
In excavation and concreting work on the building site it has been argued earlier in this thesis that the tracked mechanical barrow is the best form of site transport for the average sized contractor, also that only the larger organisations will improve productivity and final cost by purchasing special excavating machinery. An all-purpose tractor can be a great help to many contractors and can serve as a means of excavating, hoisting, transporting, etc.

The small scaffold hoists for bricks and mortar are now almost indispensable, and costing about 2/6d an hour to operate the average hoist should dispense with the need for two labourers. But the hoists must be used intelligently and as continuously as possible over a planned sequence of work.

Tower cranes have not been used in this country to the same extent as in other European countries, mainly because the average English housing site is built outwards rather than upwards as on the Continent. But Scottish house-building inclines more to multi-storey work than in England, consequently it might be thought that the tower crane should be more widely adopted in Scotland than it is/
is at present. At the time these notes were written, only one tower crane was operating in Edinburgh, and that on a three-storey distillery project.

Tower cranes are expensive, costing at least £3,000 for a medium sized outfit complete with track, etc. It has been calculated that such a crane would cost a contractor at least £12 per week for capital charges, maintenance and repair, apart from the wages of an operative to run it and fuel to keep it going. In spite of this, it is clear that some contractors in England have decided that this type of crane is a money-saver and their experience has been that, provided the building is designed with the potentialities of the tower crane in view, then the use of the crane may effect an overall reduction in costs of 3% to 4%.

For the more widely spread site, accommodating say two and three-storey blocks of houses, the type of crane which is likely to be most suitable for economic transport of materials, etc. is that mounted on pneumatic tyred wheels or on caterpillar type tracks. The photographs on the next page show how Messrs. Wimpey make use of this type of crane on a large site on which one, two and three-storey "no-fines" houses were being erected. The site is on the/
the outskirts of Edinburgh and opened up early in 1956. In the first photograph the crane is placing the shuttering in two-stoyey high sections weighing several tons each. In the lower photograph a similar crane is assisting in the concrete mixing and placing for the first and second floors. The method adopted to assist the men feeding the mixer was to scoop up and fill the mixer hopper by "dragline" action, guided by the two men. The capacity of the scoop seen in the photograph was such that a level scoop of aggregate contained a pre-determined amount of material for accurate proportioning of the concrete.
On this particular site, the contractor had three large mobile cranes, all of the type shown in the photographs, and the work of the team of operatives on the site was geared up to the capacity and speed of the cranes. The enthusiasm and output of the operatives, most of whom were unskilled, was ensured by a wages scheme which assured the unskilled operatives of £18 to £20 minimum for a 70 hour week.

Some reference was made in Vol.2 of Part One to the guyed mast as a cheap and efficient means of carrying out many modern hoisting operations. Such a rig is shown here in the photograph, it is being used to erect experimental portal frames in a Musselburgh contractor's yard. It is a metal mast and is a distinct improvement on the older type of wooden mast. Messrs John Booth & Sons of Bolton have developed a box-framed steel derrick pole which is light and easily handled and holes in the sides of the pole enable workmen to climb it readily to attend to the rope gear.
In house-building, some 150 to 200 tons of material are used in the construction of the ordinary three-bedroomed type of house, and the transfer of these materials from lorry to the point of application or construction can be facilitated to a greater or lesser degree by the use of mechanisation. The introduction of new materials and techniques of using them is opening up new opportunities for mechanisation. Only a few years ago, contractors were looking askance at such innovations as batch weighing concrete mixers, dumpers, tractor operated excavators and power tools. Now these aids to productivity are being universally accepted and it may well be that the next decade may see an even greater adoption of mechanisation in the form of tower cranes, boom concretors, platform hoists, etc.

It is not enough however, if contractors show enthusiasm and interest in mechanisation to the extent of purchasing or hiring it; the builder is not the designer of the building. He stands half-way between the producer of the mechanical equipment and the man who designs the structure that will utilise that equipment. It is for the designer to understand and provide for this/
this combination of structure design and plant adaptability and sequence that will help to justify the contractor's expense in the acquisition of mechanical plant.

Few buildings are ideally suited to the use of particular items of mechanical plant unless the designer is fully conversant with the applications and the limitations of the particular items of plant which the contractor has and is anxious to use. It is quite clear that the designer can no longer ignore these considerations. He must take these matters into account when his designs are taking shape and must avoid the expensive mistakes of the past when whole sections of multi-storey buildings were sited outside the economic range of the most highly equipped contractor's mechanical plant.

The use of machines and powered tools is growing steadily in an industry that not so long ago was beating up oxhair to reinforce plaster and scraping up cowdung to use in the rendering of the insides of chimney flues. There are signs already that the introduction of machines requiring intelligent attention and handling is raising the standard of entrant into the skilled and unskilled sections of the building industry; this may well mean the creation of a new type of building operative - without the familiar muffler and clay pipe that has public too often expressed the popular/conception of the builder and has adversely affected the recruitment of intelligent men into the industry.
The many applications of the explosively actuated hand tool described in Vol. 2 of Part One are by no means fully appreciated by the house-building industry in S.E. Scotland, yet it seems so obvious that these guns are important time savers on any average building site.

It is difficult to indicate on any but very broad lines the economic possibilities in the use of these guns compared with the employment of traditional methods. The average initial cost of a 0.22 in. calibre gun with equipment is about £35 and the cost of a cartridge and a fixing pin varies according to the charge of explosive required in the cartridge and the type of pin required to fix two or more components together. Generally it works out at nearly one shilling a shot, and from time studies made it appears that, allowing for reloading etc., an operative can fire some 40 shots in an hour under good conditions.\(^\text{1/17}\)

Against this the ordinary method of "dooking" or plugging involves cutting a hole first, inserting a wooden plug and then completing the fixing by nailing into the plug. It is reckoned that it takes an average craftsman six minutes to cut a hole and fit the plug into it,/
so at say 4/6d. per hour, the cost of the operative's time would be 3½d for cutting the hole and fixing the plug; additional time would be taken in nailing or screwing to the plug and, maybe, in cutting the plug to the desired shape. There is also the small cost of the wooden plug to be taken into account. Altogether, the cost of conventional plugging and fixing to the easiest type of walling - brickwork for example - would probably work out at about 7d. a fixing point.

It is quite clear that, even taking 9d. or 10d. as the minimum cost for an explosively actuated tool fixing, the actual cost is higher than that of the conventional method. But if the medium to which the fixing relates is hard concrete or even a steel beam the cost of the gun fixing will not vary significantly whereas the manually plugged or drilled fixing may be twice or three times more costly.

This example gives an excellent illustration of the difference between productivity and cost. A craftsman with an explosively actuated tool can make some forty fixings in hard concrete for the cost of approximately £2, and this takes one hour. The same craftsman may use conventional/
conventional methods to make forty similar fixings to hard concrete at the cost of approximately £1.15.0. (this is dependent on the craftsman taking no more than seven or eight minutes to make each hole in the concrete and to insert each plug). But the important thing to note here is that the craftsman will have taken nearly six hours to make forty fixings.

This example indicates that the new technique is nearly six times more productive than the conventional method but may be a little more costly on all but the hardest wall surfaces. It would seem then that if the manufacturers of the pins and cartridges can get their prices down by about a third, the building industry must inevitably accept this new method in preference to the old one.

Hand tools actuated pneumatically have many interesting applications to the building industry and it has been shown that they include power hammers, drills, raking bits, etc. Perhaps one of the latest and most promising development has been the range of heavy stapling or tacking hand tools that have been produced for such work as fixing roof felt, floor coverings, insulating/
insulating materials, etc. Now there is a special hammer fitted with a magazine holding up to 200 \( \frac{1}{8} \)in. tacks or staples that can be driven into felted surfaces or the like with one hand and in one blow. The same firm produces a twin-impact gun tacker, primarily developed for concrete formwork but which has subsequently proved to be useful for many other purposes on the building site. This gun is pneumatically operated and has a quick-loading magazine with a capacity of 150 3/8ths.in. to \( \frac{1}{8} \)in. staples fired by a hand grip.

With unskilled men using these pneumatic stapler/tackers on one of two identical jobs on a building site, competing against two skilled men using hammer and nails, the unskilled men completed their task in exactly four hrs. compared with the 5 hrs. 50 minutes taken by the skilled men.

A Giant tacker on the same lines as that described is now available that will fire staples or tacks up to 9/16ths.in. shank length and is thus suitable for work involving heavy or very hard materials.
What the industry requires, however is a lightweight pneumatic or electric nailer that will be self-feeding and will drive medium-sized nails at any required angle and in any position. In America where timber framed house-building prevails there are some builders who feel that the use of powered nailing tools will increase progressively as prefabrication techniques withdraw more and more labour from the site to the workshop. The American contractors also consider that the ownership of portable power tools should lie with the men that use them. Their reasons for thinking this are firstly that most of the American operatives are paid by results and it is in their own interests to use powered tools, secondly that the men who actually use the power tools will take better care of them than if they belonged to the employer.

It seems logical that the workman using the powered tool should own it, particularly when they are employed on-bonus work. It is, after all, the operative who so often seeks financial inducement rather than the inducement of work well done. In fact many operatives will change from one employer to another according to the scope for bonus earning.
The smaller building firms are bound to find difficulty in tying up their funds in powered hand tools because the capital charges on such tools cannot be justified unless the tools are in constant use. A recent survey by the University of California confirmed this when it showed that builders of more than 25 houses annually average more than three times as big an investment in tools and equipment as builders of less than ten houses a year.

In Vol. 2 of Part 1 I have referred to the usefulness of the "Dinkum" type tractor which combines a bulldozer at the one end with a back-acter excavator at the other and I suggested that this multi-purpose type of mechanical aid was the most suitable for the average sized contractor. In summarising these notes on mechanical equipment I think I would go further than this and recommend the development of a multi-purpose machine that could be used to transport materials, excavate, fill and grade earth in most site operations, and also act as a generating plant for the pneumatic power supplying vibrators, hammers, paint sprays and other powered hand tools on the building site.

Such a machine would be ideal for the average sized contractor, for it could be moved from site to site quite easily and would thus be rarely idle.
Modular Coordination.

It is difficult to make a useful assessment of the influence of modular coordination, as a new technique of construction, upon the house-building industry in this country. There has been little or no application of modular planning to housing work, though the Ministry of Education has obtained encouraging results by basing the design of many new schools on a 40 inch grid.

It seems so obvious that the adoption of a recognised module in this country is bound to assist standardisation and prefabrication in relation to most types of building work and consequently will serve to lower building costs. Yet we have still not arrived at final agreement on this important question of the module. There are still those who think that we should go our own way in this country and settle on a three inch module to accord with the general run of brick courses in British building; then there are those who are in favour of the development of a number pattern working through three dimensions and producing a complex pattern that seems to include almost every number above unity. In fact it seems to set out to please everyone.

In/
In America, attempts have been made from time to time to obtain some broad indication of the influence of modular coordination upon productivity. In 1947 the Small Homes Council of the University of Illinois and the United States Department of Commerce's Office of Technical Services sponsored the construction of six houses, three built in brick walling and the other three in timber-framed construction. In this experiment, conventional construction methods were applied to two houses - one brick-built, the other timber-framed. Then another pair was built so as to employ the technique of modular coordination as far as possible. Finally the last two houses were built, using the modular technique but taking advantage of the lessons learned during the construction of the second pair of houses.

The module adopted in this experiment was 4 in. and time and motion studies were employed so that accurate observation was made and all operations timed, noted and analysed. The tabulated results from this experiment are noted down in the following page, from which it will be seen that for an entire house a saving of 21% in manhours was achieved through the operation of a modular technique of construction, and although too much cannot be taken for granted from such a small-scale experiment the result undoubtedly/
undoubtedly supported the view that standardisation through modular planning means improved productivity.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Conventional Manhours</th>
<th>Modular Manhours</th>
<th>Manhour Saving %</th>
<th>%age Saving in Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation and floor</td>
<td>257</td>
<td>231</td>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>External Walls</td>
<td>262</td>
<td>218</td>
<td>18</td>
<td>1.0</td>
</tr>
<tr>
<td>Roof</td>
<td>375</td>
<td>277</td>
<td>26</td>
<td>2.2</td>
</tr>
<tr>
<td>Interior</td>
<td>412</td>
<td>251</td>
<td>38</td>
<td>3.6</td>
</tr>
<tr>
<td>Factory-made items</td>
<td>534</td>
<td>440</td>
<td>18</td>
<td>2.1</td>
</tr>
<tr>
<td>Services (Plumbing, Heating, Electrical)</td>
<td>163</td>
<td>156</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>75</td>
<td>67</td>
<td>8</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Note. This analysis refers to the timber-framed type house. All houses were one-storey, consisting of five rooms and a basement making up a total floor area of 811 sq. ft.

A more recent example of the influence of modular method on productivity and cost was referred to in the Modular Quarterly (Spring, 1946) when it was stated that despite/
despite earlier estimates that the giant General Foods Corporation's new headquarters building in New York would cost the client $150,000 more if based on modular planning, in the final analysis it was shown conclusively that the construction costs were $29,000 to $40,000 less than they would have been without modular dimensioning.

In this country there are few published instances of improved productivity through modular building, though there must be many builders who have realised unexpected profits through early completions. An indication of this was given by Mr. Peter Gardiner, speaking to the Modular Society early in 1956, when he said - "Up to the present too few builders have had sufficient experience of modular building to be aware of the vast saving in overheads that can be achieved by the reduction of time on the job. For instance, on one of our Thermagard contracts, the delighted builder's foreman received £2,000 from his employer at the end of the job, as he had an agreement which gave him a third share of all profit made over the target profit. The contract was something over £60,000. The contractor finished three months ahead of schedule and presumably made 10% over and above his target profit."
Modular bricks have not so far been used in this country and consequently no data are available concerning their influence on building costs. The 8in. by 4 in. by 4in. modular bricks produced in America are said to have been responsible for major economies in walling. According to observations made on a selected unit of 8 houses the brickwork was completed in 27 hours by 18 workmen. This worked out that the 6,400 sq.ft. of walling in the 8 houses took a total of 486 manhours to build, or 72 manhours per 1,000 sq.ft. of wall.

The brickwork contractor responsible for this work stated that a bricklayer could lay about 800 standard bricks in an 8 hour day as compared with 500 to 600 modular bricks. But the saving in time and mortar material per sq.ft. of modular brick walling was equal to nearly 25% over standard brickwork.

A comparison of the estimated cost of modular brickwork against standard brickwork is set out on the next page.
Estimated Cost Comparison between Standard & Modular Brickwork.

<table>
<thead>
<tr>
<th>Item</th>
<th>Standard Facing Brick</th>
<th>Modular Brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bricks used per 1,000 sq.ft. of wall.</td>
<td>7,000</td>
<td>4,500</td>
</tr>
<tr>
<td>Cost of 1,000 bricks.</td>
<td>$45.00</td>
<td>$51.50</td>
</tr>
<tr>
<td>Cost of brickwork per 1,000 sq.ft. of wall.</td>
<td>315.00</td>
<td>231.75</td>
</tr>
<tr>
<td>Labour and mortar cost per 1,000 bricks.</td>
<td>46.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Labour and mortar cost per 1,000 sq.ft. of wall.</td>
<td>322.00</td>
<td>270.00</td>
</tr>
<tr>
<td>Total cost per 1,000 sq.ft. of wall.</td>
<td>637.00</td>
<td>501.75</td>
</tr>
</tbody>
</table>

The cost-saving illustrated by these figures suggests that there is a field here in this country for substantial economies in brick walling using modular bricks. As stated at some length in Vol.1 of Part One, I consider that the 8in. by 4in. by 4in. nominal dimension to be the most satisfactory, though many authorities are of the opinion that, to quote Mr. Hartland Thomas, "there is really no need and no advantage in brickwork becoming modular until a really large hollow clay facing brick is produced."
While brick manufacturers are selling all the standard sized bricks that they can produce it is unlikely that they will give any serious thought to the production of a brick with dimensions based on the 4in. module. The process of changing over to a completely different size of brick, with all the complications and expense of installing new equipment, is something that will never be undertaken by the manufacturers unless the sharp edge of competition drives them to do so - and there is very little competition in the brick industry today except, perhaps, between the National Coal Board and the big combines.

So far as Scotland is concerned, the N.C.B. could probably influence the general run of Scottish contractors to use modular bricks if they were produced cheaply enough, for competition from the large London combines does not extend effectively to Scotland owing to the transport factor. The main drawback however, to the introduction of a modular brick in Scotland would be likely to arise from the fact that facing bricks are not, as yet, produced in any significant quantities by the N.C.B. and modular common bricks would hardly combine economically with/
with standard English facing bricks.

It may be however, that the new National Coal Board brickworks manufacturing facing bricks at Newton, Lanarkshire, will be the forerunner of a large number of such brickworks specialising in the production of facing bricks. The new works, opened in 1956, is producing a red facing brick of quite reasonable colour from the red laminated shale which is mined nearby.

The new manufactory employs a high degree of automation and is designed to produce one hundred thousand bricks a week with only a staff of some seventeen. The bricks have a good compressive strength, samples that I have tested have resisted compression beyond 5,000 lb per sq. in., more than twice the strength of the average N.C.B. common brick manufactured in Scotland.

If the National Coal Board could extend this manufacture of good quality facing bricks to the extent of eliminating competition from the English brickmakers then it might be possible for Scottish modular bricks to be introduced to the industry. In any case it would be all to the good if the N.C.B., as a nationalised concern, were to be encouraged by those in high places to experiment with the production of a modular brick. There is no other organisation in Scotland sufficiently equipped to do this.
Building Research.

The emphasis on craftsmanship in the industry is steadily giving place to the application of science as new materials and processes continue to be introduced. The work of the Building Research Station has expanded greatly since the war in response to a substantial increase in the volume of building, but there is no reason to suppose that public funds will be available to finance an unlimited expansion of the activities of the B.R.S. Already there have been certain economy measures by the Government which have placed severe restrictions on the work of the Station.

There is much to be said for those who argue that since the building industry benefits from this research then the industry should initiate and pay for such research. In the report of the D.S.I.R. for 1953-54 it was pointed out that "the building industry, as a whole does not appear to make so large a contribution to research for its benefit as do most industries, and as it might do". This is very true and has a particular application to the industry in Scotland where little or no research has been done by private firms.

One or two of the larger firms, originating from England/
England are able to benefit from experience gained in English-based research establishments and one or two of the more enlightened smaller firms such as Cruders of Musselburgh cooperate with universities or technical colleges in certain research projects and have their own modest laboratory facilities. The Scottish Special Housing Association do a little research in connection with no-fines concrete housing and other special types of houses but there is little organised building research in Scotland apart from that which is done at the Scottish B.R.S. at Thorntonhall.

It may well be that this lack of interest in research is yet another consequence of the existing pattern of small trade firms in Scotland, for it is usually only the larger firms that have the resources to support expensive research activities.

Quite recently the B.R.S. at Watford has advertised a Research Fellowship in connection with the study of brick packaging and the Architects' Journal is sponsoring a Fellowship also. The Royal Institution of Chartered Surveyors has also made an announcement in the Institution Journal for May 1956 to the effect that Scholarship or other awards are to be made to assist research/
research into matters relating to the theory and practice of surveying in any of its branches. The (English) National Federation of Building Trade Employers has just decided to contribute £2,000 a year, for five years, to the Building Research Station, but one has yet to learn what contribution is contemplated by the Scottish employers' organisations.

With regard to the question of who benefits from research the point is often made that it is the client and not the builder who reaps the ultimate benefit in terms of cash and consequently it is the client, in the shape of the British taxpayer, who must foot the bill. This might well be so but there will always be a few contractors who are more progressive and sensitive to the benefits of research and are quick to realise these benefits in their construction methods and in their schedule rates. It follows then that these contractors will be more likely to expand their organisations than otherwise.

The responsibility for initiating and paying for research should be shared by the material producers in reasonable proportion for in house-building, between 50% and 60% of the price of the finished dwelling is represented by materials, the labour costs in erection amounting to 30% to 40% and profits and oncosts making up the balance of 10% to 15%.
CONCLUSION.

The basic essential for higher living standards throughout the world is increased productivity in every field of endeavour, and improved productivity relies upon the skill and imagination with which inventive genius is applied to the development of available resources.

These notes have shown that inventive genius with regard to the building industry has not been lacking; rather has the fault lain with the industry itself in failing to apply fully the results of research and invention. Moreover, where progressive firms have applied new constructional techniques on house-building work it has been shown, time and time again, that the majority of these firms either cannot or will not say how and to what extent the new methods have increased productiveness and reduced cost. The cost analyses at the end of this Volume were based on priced Schedules (Bills of Quantities) that were extremely difficult to obtain, because it was next to impossible to persuade contractors to publish their Schedule rates - even in a thesis having a limited circulation. It was also found that the majority of the suppliers of new materials or appliances designed to save cost/
cost were unable to provide a convincing cost comparison of their product against conventional materials or methods. In fact a considerable number of producers failed to reply to written requests for such cost comparisons.

In spite of these difficulties which have hampered this critical examination of new techniques, it has been possible, here and there, to produce what is hoped are new and interesting data that will be helpful to the house-building industry when published through the wider medium of the technical press and the Journal of the Royal Institution of Chartered Surveyors. Progress stems from the interchange of ideas, and the building industry, the second largest in this country, will continue to lag behind other industries until this is fully understood and until contractors are prepared to pool information for their mutual benefit.

In these last pages an attempt is made to forecast future developments in the building industry over the next 25 years. This forecast is necessarily cautious, for allowances must be made for the industry's preference for traditional methods. Changes will be brought about only by the sheer pressure of economic necessity.
Future Developments.

There are signs that 1957 may see some recession in house-building activity, for the cumulative effects of the recent credit restrictions, the higher rates of interest, the difficulties experienced by building societies in attracting funds and the reduction in the volume of Local Authority housing following the subsidy cuts - all these will tend to slow down the present pace of house-building. On the other hand, such a recession would give a considerable impetus to the drive for increased building efficiency through improved organisation and constructional techniques.

If the present rate of change in operational techniques and in the production of new building materials is maintained throughout the next 25 years we may expect to see some remarkable developments in the house-building industry. It is practically certain that the use of concrete interlocking roof tiles will become as popular in Scotland as it is in England at the present time. Built-up felt coverings are also likely to be more commonly adopted in Scotland, particularly on low pitch and mono-pitch roof types.

In walling the present trend towards the use of larger/
larger constructional units is likely to be intensified and there is also likely to be an increase in the use of improved lightweight aggregates for these wall units, in the pursuit of economy through weight saving and directed towards the achievement of better standards of thermal insulation. The fly ash produced in the Scottish power stations and the contents of the Scottish shale "bins" will probably be the subject of accelerated research and experiment, particularly through pelletisation and firing in sintering plants.

The use of ready-mixed concrete may be further extended in Scotland with large central supply depots set up in towns other than Glasgow. Good concrete aggregates are surprisingly scarce around Edinburgh and a centralised mixing plant could take advantage of bulk supplies of the better aggregates, particularly fine aggregates, from the more distant sources.

Precast concrete floor beams made up from lightweight aggregates may, if produced cheaply enough, compete keenly with the traditional timber floor. It is unlikely that prestressed concrete planks will ever make an ideal floor for housing purposes because they usually have such a poor degree of thermal insulation, but future developments in/
in flooring may include a combination of prestressed concrete beams and clinker block fillers as described under Floors in Vol. 2 of Part 1.

Finishings involving wet processes are likely to become less common in house-building as new types of building board and linings are produced at competitive prices and as plastic or other types of formwork are developed which give a completely satisfactory finish on concrete wall and ceiling surfaces. It is certain that the painstaking research which produced the thermoplastic tile will go on to devise an inexpensive finish that will be more resilient and colourful, and at the same time will be less prone to marking and disfigurement from ordinary movements of household furniture.

The drab harled external finishes to Scottish houses may slowly give place to something more colourful, if only to panels of exposed aggregate. The great obstacle which stands in the way of the adoption of new methods of external wall finishing is the deep rooted conviction of so many Scotsmen that the Scottish climate is far more severe than anywhere in the British Isles! Yet the joint observations of the Garston and the East Kilbride Building/
Building Research Stations have shown conclusively that certain other parts of England suffer more extreme conditions of weather than the populated parts of Scotland.

The advantages of prefabrication have been fully set out in Vol. 1 of Part One, and there seems little reason to doubt that the proportion of off-site prefabrication in house-building components will continue to grow. The future prospect for the universal adoption of modular co-ordination during the next 25 years is rather less certain, for there are so many obstacles to surmount. Perhaps the greatest obstacle is represented by the fact that manufacturers of building components have their own standard sizes suiting equipment which they are loath to scrap, but there are other people concerned with building who are not entirely blameless in this connection - much more interest could be shown by the great majority of architects and the British Standards Institution could make a contribution to progress if an early decision on the module were made. There can be little doubt that the universal adoption of the principles of standardisation could make a tremendous difference in the level of productivity in the building industry.

The revolutionary changes in materials and techniques/
techniques which are likely to come about in the next 25 years will doubtless be slowed down by the resistance of the various craft organisations to the inevitable emergence of a new semi-skilled type of operative whose function it will be to "fix" the prefabricated components of the new 1980 houses. There are bound to be many long and bitter industrial disputes over such early questions as "who shall fix the walling panels, the bricklayer or the carpenter?"

In the beginning it is pretty certain that there will be many restrictive practices and craft rivalries. This is happening in the American building industry at the moment and is the cause of many curious preferences by architects when selecting the material or technique for a particular form of construction. For example there is a reluctance to specify steel or aluminium systems of floor decking because the fixing of this is claimed by the steel erectors who earn higher wages than carpenters.

How long it will be before "general fixers" are established in the industry will depend on the demand for buildings and the consequent strength of the craft unions but I would venture to prophesy that this change will come about within the next 25 years.
In many industries other than the building industry the use of systematic analyses of working operations has long been standard practice, and increases in output of the order of 25% to 50% are considered to be normal as a result of this work study. The building industry is one of the last industries to give serious consideration to the benefits of work study, and it seems reasonable to prophesy that in spite of the difficulties involved as application to building operations the future years will see more and more analytic investigation and measurement of building processes and techniques.

In addition to work study we may see the introduction of kinetic methods based upon the conception of employing the minimum muscular effort for a particular job and the development of tissue elasticity and muscle co-ordination. So many site operations in the building industry depend upon muscular effort that is so often misapplied.

The word "automation" has now become familiar to everyone, if only through the medium of the newspaper reports on the 1956 industrial disputes in the motor industry, and as yet it would seem that automation has little/
little application to building work. But it is inevitable that automation will be applied within a few years to a large part of the woodcutting machinist's work, for it is already happening in the United States where advanced mechanisation has been achieved in many woodworking factories. At one saw-milling undertaking in New Mexico automation is already established and 50,000 lineal feet of 4in. by 4in. timber are cut from logs at every shift by six men.

Automation is likely to accelerate the development of prefabricated components for building work, for it will reduce the cost of the factory-made article, and this is just what is needed to put prefabricated components on a competitive footing with traditional methods.

The present drive for a substantial increase in the number of trained technologists, initiated in 1956 by the White Paper on Technical Education should have an important influence on the long term trend of productivity in the industry. Full time courses in Building Technology, now available at the Royal Technical College, Glasgow and the Heriot-Watt College, Edinburgh, should attract a greater number of students than hitherto. Indeed the enrolment for the Heriot-Watt College course, 1956/57 is higher than it has/
has ever been. It is early yet to make any forecast concerning the proposed new national award for technologists, the "Diploma in Technology", for at the moment of writing the National Council for the administration of the new award has only just been set up and applications from colleges for recognition of courses have not so far been invited. If this National Council is sufficiently discriminating and the total number of approved colleges is limited to six or at the most, eight, of the highest rank, then this new award may well achieve its purpose - the creation of a technological qualification which is unquestionably of honours degree standard. Such a qualification will then attract the right type of student and the building industry will benefit from it.

These notes concerning future developments in the building industry conclude this thesis which has sought to show by examination, experiment and argument that new and improved methods of construction are abundantly available to the industry. Will the industry make use of them or, with an ever backward glance, will it rest content with the thoughts of an age that is past and thus cause prices to rise to an extent which will imperil the industry's very existence?
Elemental Cost Analyses of Low-cost Terraced Two-storey Houses and Three-storey "No-fines" Concrete Flats.

The analyses reproduced in this Appendix were made up from priced Schedules (Bills of Quantities) for work done during the period late 1954 to early 1955. Two similar types of houses were used in the analyses A and B, each representative of current non (or new) traditional housing seen all over Scotland. The cost build-up of houses such as these, with a total area of only 670 superficial feet or so is limited to such an extent that one can hardly expect to reveal any startling comparisons between one type and another. However the following observations will perhaps be of interest and serve to show how the cost of elements can vary within a given total.

Structure

It will be seen that Type B has a structure which is almost 4½ more expensive than Type A, in spite of a saving on foundations of 5d. per ft. super. This is due largely to the cost of the external walling in Type B being nearly 50% more than in Type A, and reference to the Schedule showed that a larger area of walling was responsible for this. The use of Finlock gutter creates a need for more d.p.c. and this is brought out in the analysis. The ground floor in Type B is a solid one and this accounts for a slight increase over the hollow-joisted floor used in Type A.

There is little in this section that could not have been obtained from the priced Schedule, yet it is interesting to/
to compare certain of the elements, for example take the roof covering, and see how near the elemental costs are to each other.

Wall Panels

The total difference here is not great, and one would not expect to see much variation in the cost of the glazing which is probably done by a sub-contractor and is down to a rock-bottom figure in both instances. But the differences in the other two items are significant, for the contractor responsible for the Type B house has for a long time specialised in the production of factory-made joinery, particularly flush doors, and it is obvious that the combination of builder and prefabricator will make for keen prices on doors and windows.

Partitions.

Both contractors prefabricate the internal partitions but it seems that in Type B a saving is effected somewhere, particularly so because the Type B partitions are finished face and the others are skimmed. Another variation occurs in the cost of the internal doors - this has been explained in the previous section.

Finishings

It was not possible to get a comprehensive breakdown of the finishings in Type A, owing to the grouping within the/
the Bill of whole series of items such as skirtings, drip boards, fuel bunker, etc., under the heading of Internal Components. The wall finishing for Type A was conventional two-coat plasterwork and cost 10.5 pence per foot super as against 7.6 pence for plasterboard fixed to nailing courses as used in Type B. External wall finishing is more costly for Type B because it is an end house.

**Equipment.**

The footpaths to be provided in Type A extend over a greater area than in Type B - according to the Bill the difference is 29y.s. against 9 y.s. One would have expected the end house to have had the smaller area of footpath but 9 y.s. hardly appears sufficient according to the plan. Again, the difference in the elemental cost is not in the same ratio as the area to be covered respectively and reference to the Bill showed that the contractor for Type B wanted more for his footpath construction, yet the specification was the same in each instance.

For the reason already mentioned, the item Ironmongery could not be brought out in the analysis of Type A. The figure of 5.9 pence f.s. in Type B is quite a bit higher than the 3.7 given for the West Riding School Analysis but this is understandably due to the increased number of doors and small windows in houses.

The/
The fireplace was included under equipment in both instances because it provided domestic hot-water. Type B obviously provides the more expensive fireplace of the two.

Services.

Electrical installation and external drainage are practically the same in both analyses. The plumbing in Type A is more costly, yet according to the Bill and the plans there is little difference in the service provided.

Contract.

Provision has been made here for the erection of temporary buildings, watching, welfare, temporary roads, insurance and various other general items. The lumping together of these items is understandable perhaps on small contracts but it would be interesting to have a little more information about the respective allocations to welfare and scaffolding.
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