THE UNIVERSITY OF ASTON IN BIRMINGHAM

DEPARTMENT OF BUILDING

'THE INCIDENCE, CAUSES AND PREVENTION OF DEFECTS IN THE CONSTRUCTION OF NEW HOUSES'

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SUMMARY

One thousand cases of disputes about defects, taken from the records of the National House-Builders Registration Council, are analysed.

Different types of defects are identified and quantified. Criteria of frequency, frequency/cost and frequency/seriousness are applied and the 40 most important defects identified. The causes and means of preventing these defects are considered.

Quantitative patterns of the incidence of defects are given for building elements and stages, trades, cost groups and regions. The responsibility for defects is allocated to the design, site management, workmanship and component manufacture functions. The defects are analysed according to the size of builder responsible for them. The incidence of defects in builder size groups is compared with the number of houses built by the size group and reasons for differences are postulated.

The defects are sorted into 11 groups such as structural, damp penetration, building movement and incomplete work. The relative importance of each group is found for different regions, geographical areas and types of complaining purchaser. Technical and behavioural factors causing differences are identified. The most contentious groups of defects and alleged defects are noted. Tolerances are proposed as objective means of distinguishing between defective and non-defective work in these groups.

Schedules and check lists are built up from the analysis of defects to assist in systematic quality control of house construction. The place of the quality control function in the builder's management structure is discussed. Because all houses contain some defects, a system of demerit marking is proposed in order to define what is a defective house. The constraint of purchasers is recommended in relation to minor defects and financial sanctions against builders who do not remedy defects timeously is also recommended.

CONTENTS

TABLES IN THE TEXT

FIGURES

APPENDICES

Appendix A. Schedules

Appendix B. Defect Classes

BIBLIOGRAPHY

TERMINOLOGY

Unless otherwise indicated, terms are used in this thesis with the following meanings:-

COUNCIL) N.H.B.R.C.)	'The National House-Builders Registration Council'.
BUILDER	(a) 'A registered house-builder'. (b) 'The person(s) or organisation(s) carrying out the construction process'.
CONSTRUCTION	'That part of the building process which consists of detailed design and the management, supervision and execution of work on site'.
PURCHASER	'The person complaining about a new house'.
HOUSE	'House, bungalow, flat or maisonette including garage and site works within the curtilage'.
NEW HOUSES	'New house(s) built for sale in the private sector in England and Wales'.
AGREEMENT	'The House-Purchaser's Agreement entered into by a builder and a purchaser and under which the builder must remedy defects due to his non-compliance with the N.H.B.R.C. standard specification provided that the purchaser has reported the defects to the builder timeously'.

SPECIFICATION — 'The N.H.B.R.C. standard specification to which all registered house-builders must build'.

DEFECT — (a) 'A defect considered by an officer of N.H.B.R.C. to be valid under the terms of the Agreement'.
Limited to defects occurring within two years of occupation of a house.
By definition in the Agreement, the terms excludes maintenance work, such as making good minor shrinkage and damage due to fair wear and tear.

(b) When used quantitively, the term means the number of cases in which any defect class occurs.

CASE — 'A dispute about defect(s) referred by a builder or a purchaser to N.H.B.R.C. for investigation and advice on whether to not defects are valid under the terms of the Agreement'.

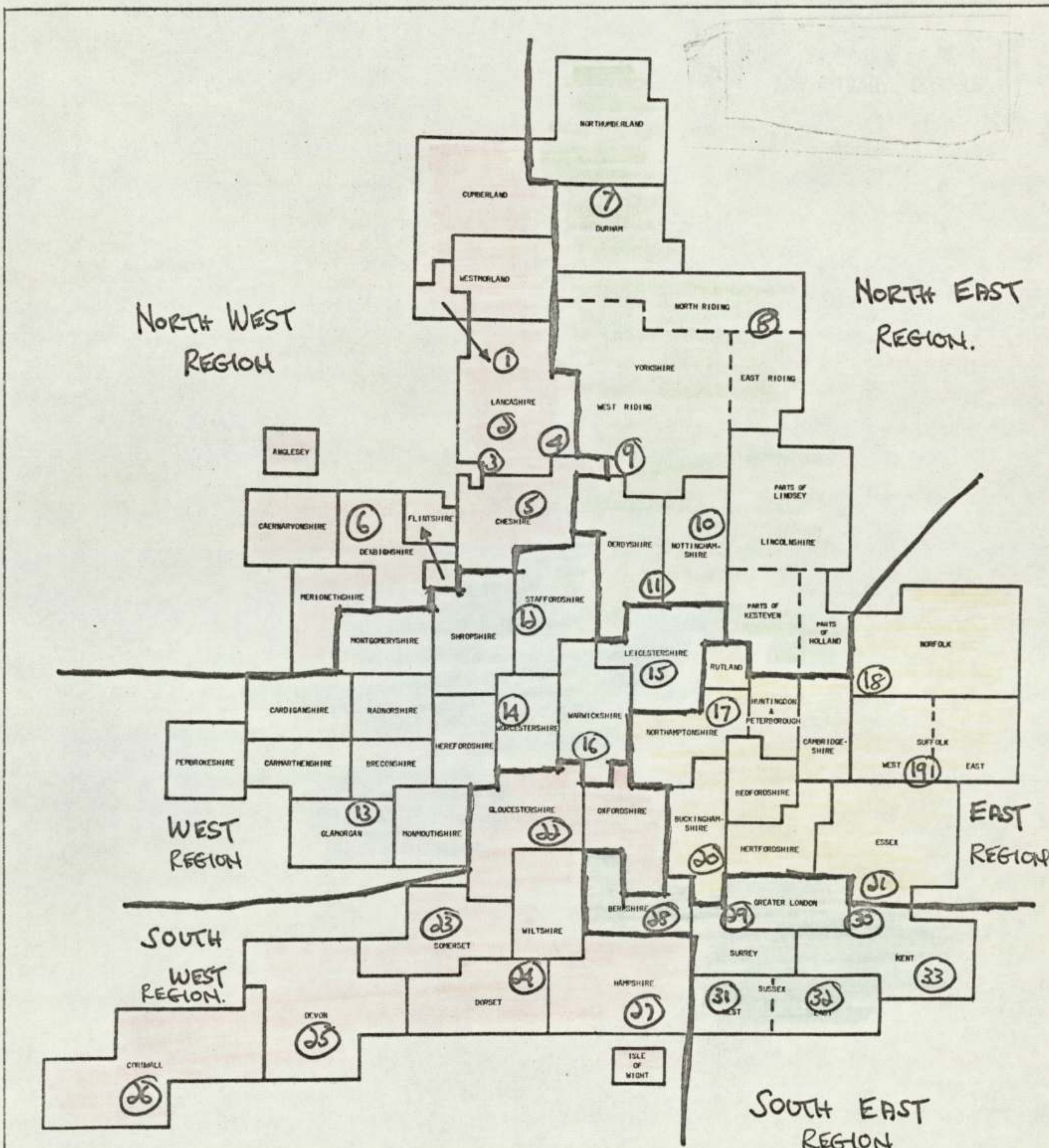
DEFECT CLASS — 'One of the 375 different classes of defect identified in this thesis'.

DEFECT GROUP — 'One of the 11 groups into which the 375 classes are grouped'.

REGIONS — 'The operating regions of N.H.B.R.C.' See Figure 1.

AREAS — 'The operating sub-regional areas of N.H.B.R.C'. See Figure 1.

Note: Regions and Areas, although disparate in terms of geographical size are equal in terms of numbers of new houses built.



(N) Centres of areas.

FIGURE 1. NHBRC REGIONS AND AREAS.

INTRODUCTION

Subject of thesis.

The subject of this thesis is 'The Incidence, Causes and Prevention of Defects in the Construction of New Houses'. The terms 'defect', 'construction' and 'new houses' are defined under Terminology (See page 1).

Origin of thesis.

Each year several thousand complaints about defects in new houses are brought to the attention of the National House-Builders Registration Council. In these cases, the purchaser contends that the builder has failed in his obligation under the Agreement to remedy defects. In many cases, an officer of the Council will inspect the alleged defects and suggest which of them the builder should remedy. The records of these complaints and investigations are unique as an industry-wide and representative source of data on this subject.

The scheme under which registered house-builders must enter into the Agreement and remedy defects has grown rapidly since 1965 until now it covers all but 1-2% of the private house-building industry. Some small studies of the data have been made during the 1965-9 growth period but in 1970 the time was felt to be ripe for a carefully planned, systematic study. It is the results of this first full study that are presented in this thesis.

Objects of thesis.

The first stage of the research was to make a computer analysis of the defects contained in a representative sample of cases. This is done for a block sample of 1,000 cases. The objects were to find out what were the defects, which were the most common and most important, how they could be most meaningfully grouped, to make inter-regional comparisons, to analyse the defects according to criteria such as building stage, cost, who was responsible, seriousness of the defect, and to establish general patterns and trends.

By its nature, the data on which the thesis is based is not just clinical and technological. It consists of defects of which purchasers have complained and which builders have failed to remedy. The motives for complaint and for failure to remedy defects are germane to the correct interpretation of the data. These behavioural factors are studied in sub-samples of the 1,000 cases analysed.

When the technological and behavioural causes of defects/complaints have been identified, they are put together into a matrix of causal factors. The last object was to propose means of preventing defects/ complaints. The proposals include technological points, schedules to enable builders to check their work systematically, and changes in the Agreement to impose a greater discipline on both builder and purchaser.

As this is probably the first study of its kind made anywhere in the world, its objects have been construed as the identification of trends and probable causal factors. The object has not been to establish causes using sophisticated statistical techniques such as those of regression analysis.

<u>Scope of thesis.</u>

The thesis applies to all new private sector housing in England and Wales but not to Scotland and Northern Ireland. The houses studied were built in the late 1960's. The defects are those which occurred within two years of completion of the houses. The majority of the houses are one or two storeys high and of traditional construction. A few low rise blocks of flats occur but virtually no truly non-traditional systems.

Plan of thesis.

The thesis is divided into five parts, as follows:-

Part I - Review of literature and previous work.

Part II - Method : Data collection.

Part III - Results : The incidence of defects.

Part IV - Discussion of results : The causes of defects.

Part V - Recommendations : The prevention of defects.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Paragraphs

THE INCIDENCE OF DEFECTS

53 98% of new house purchasers are given satisfaction by their builders without need to complain to N.H.B.R.C.

54 Most defects cost very little to remedy individually. (Average £100) The 1,028 cases analysed are estimated to account for a total remedial cost of £116,000.00, i.e. £113.00 per house.

61 Few defects occur in the early stages of building but these few are costly: The majority of defects are in finishes.

62 The average numbers of defects complained of is 5.2. 30% of purchasers complain of only 1 defect.

63-9 Defects are more prevalent in the West and South than they are in the East and North. The higher figures in the West are due, in part, to greater incidence of damp penetration defects.

71 Defects are more prevalent amongst builders who trade as limited liability companies.

72 Defects are more prevalent amongst small builders than large in proportion to the numbers of houses built.

82 Forty defects are selected as being the most important according to criteria of frequency or frequency/cost or frequency/seriousness.

Paragraphs

THE CAUSES OF DEFECTS

84-90 All defects are attributable to a person, i.e. designer, site supervisor, operative or material manufacturer. Costly defects are mainly attributable to designers. Site supervisors and operatives are together responsible for some 70% of all defects. One defect in five is visible at the time of handover of a house to the purchaser.

92 Damp penetration defects are due to carelessness or failure to follow local vernacular detailing.

93 Groundwork defects are due to the increasing use of low quality building land.

94-7 Defects attributable to initial movement of the building, such as cracking, shrinkage, warping, etc., are due to a combination of factors including the advent of central heating, the use of slender section joinery and the use of aerated concrete blocks. A new philosophy of designing for movement is needed.

99-101 Purchasers in the professional classes complain more than purchasers in lower social classes due, possibly, to greater expectations and ability to understand, and act on, their legal rights.

105-1[illegible]1 Failure by the builder to remedy agreed defects is more significant as a cause of complaint than disputes about what is, or is not, a defect.

Paragraphs

107 A builder who intends to stay in business for only a short time may be more reluctant to remedy defects than one who intends to build up a long term reputation.

108-9 Financial instability and recent board changes are characteristics of small firms who have failed to remedy defects.

115-116 The most controversial items are those in the initial building movement, building inaccuracies and general unacceptable workmanship defect groups.

117-129 Geographical differences in defect incidence are due to the interaction of factors including climatic, general economic and labour history, the sophistication or otherwise of the market, the size of builders and their efficiency in remedying defects and the incidence of sub-contracting.

THE PREVENTION OF DEFECTS

131 'Important points to check' schedules are given for design personnel, site management and each trade.

132 A check list is given to assist in the observation of defects visible at the time of handover.

134 The man responsible for production on site should not also be responsible for quality. The production man and the quality man should report independently to top management.

139 A schedule of building movement tolerances is proposed.

Paragraphs

142 Defects visible at time of occupation should only be the builder's liability if they are reported to him within three months of occupation.

143 Consideration should be given to the fining of builders who are found guilty in the delay of remedying agreed defects.

144 In the case of less serious defects, a liability to remedy should only exist if the house is found to have a total demerit value above a defined norm.

PROPOSALS FOR FURTHER RESEARCH

146 A sample of new houses should be surveyed to ascertain:-

(a) the standards of accuracy to which they are built.

(b) the standards of non-quantifiable items relative to standard samples.

(c) incidence and total demerit value of the less serious defects.

Upon completion of this work, definitive criteria should be drawn up for the adjudication of controversial items and for defining what is a defective house.

PART I

REVIEW OF LITERATURE AND OTHER CURRENT RESEARCH

LITERATURE OF BUILDING DEFECTS AND TOLERANCES

1. This survey of literature and current research has been compiled from work done within the N.H.B.R.C. over the period 1965-71, from general reading during research period and from international enquiries made through the London Embassies of European and English speaking countries. As will be seen, the international enquiries reveal very little information.

GOVERNMENT AND RESEARCH BODIES

2. Some one third of British building industry resources are spent on the maintenance of existing buildings. Considerable research effort is now being directed to finding means of reducing this expenditure. The former Ministry of Public Building and Works organised a series of conferences at which technical problems were discussed. The proceedings of these conferences[1] identify problems such as instability of joinery due to atmospheric conditions, loose wall tiling and damp penetration at the jambs of openings. In addition to being maintenance problems, these are common defects in new houses. The proceedings offer no radical solutions to these problems.

3. Problems arising from the instability of timber have been investigated by the Forest Products Research Laboratory, who have suggested that an additional capital expenditure of £0.25 - £0.50 on the external doors of houses is justified to offset the cost of remedying defects[2].

4. A C.I.B. report deals at length with problems of damp penetration of buildings but is only relevant to traditional house construction when it considers timber cill and threshold details[3]. The Building

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1. Proceedings of various M.O.P.B.W. Building Maintenance Conferences published by H.M.S.O.
2. W.T. Hide 'Timber Components'. Timberlab News. September 1970.
3. CIB Report: 'Weathertight Joints for Walls'. Norwegian Building Research Institute. 1968.

Research Station Advisory Service publication on protection from rain is more pertinent and brings together in one small volume basic details for rain exclusion[4].

5. A Canadian report discussing defects in ten year old houses in Canada identifies spalling concrete drives and failure of mechanical parts, such as water tanks, taps and window fittings as common problems[5].

6. <u>CONCRETE SOCIETY</u>

[6]The proceedings of a Concrete Society symposium on 'Design for Movement in Buildings' is the most comprehensive study of movement which is the cause of many defects in new houses. The different types of movement are clearly identified. These are structural movement caused by deflection or creep and temperature and humidity movement. The main thesis is that movement in new buildings is inevitable and that buildings must be designed to minimise its effect.

7. The effect of mining subsidence and how to design for it are treated at length. The importance of differential movement in structures is emphasised and, in particular, the relationship of partitions to main structures. They will be shown later in this thesis that this is a very important point.

8. The paper on internal detailing is disappointing because it makes unrealistic suggestions. It suggests that door casings should be

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4. '<u>Protection from Rain</u>'. Building Research Station Advisory Service. April 1971.

5. A.E. Veall '<u>A Survey of Housing Performance</u>'. Build International. Jan/Feb. 1970.

6. '<u>Design for Movement in Buildings</u>'. The Concrete Society. October 1969.

made up of numerous small mouldings to minimise shrinkage and that only quarter sawn timber should be used. Plastering is correctly identified as a problem area for movement defects. The suggested means of prevention are either the separation of plaster from the sub-strate by means of lathes or by the substitution of another material for plaster. These proposals apparently apply to brick and blockwork walls. The cost of lathing in such circumstances is not mentioned and no lead is given of possible alternative materials to plaster[7].

BOWYER

9. Bowyer's book 'Guide to Domestic Building Surveys' is valuable because it outlines very succinctly a systematic way of surveying a house and noting defects. A check list is provided for each part of the house identifying common symptons and the possible defects giving rise to them. The book is a valuable example of ordered, precise and diagnostic thinking[8].

FELD

10. Feld's 'Construction Failure' consists mainly of studies in major building failures. The book makes two outstanding general points. The first is that more emphasis needs to be given in technical education and training to the incidence, causes of failure and defects. The second is that many faults are due to a repeated and uncritical use of unsuitable details and practices. Feld suggests that research should be undertaken to identify such details and practices. This thesis is intended to report such research[9].

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7. J. Brandenberger. 'Internal Details that Permit Movement' - Design for Movement in Buildings. The Concrete Society. 1969.
8. S.T. Bowyer 'Guide to Domestic Building Surveys'. The Architectural Press. 1971.
9. J. Feld. 'Construction Failure'. Wiley. 1968.

McKAIG

11. McKaig's 'Field Inspection of Building Construction' is a book for Clerks of Works. It considers the traditional techniques for checking the quality of materials and workmanship during construction. It recognises that some times decisions have to be taken on whether work is just acceptable or just unacceptable, in a situation where no quantitative criteria are available. The problem is recognised but in only one case is there any attempt to suggest a quantitative criterion. This one suggestion is that the maximum permissable twist in a door should be ¼in.[10]

RAGSDALE AND RAYNHAM

12. The writers of 'Building Materials and Practice' are members of the Central Laboratory staff of the largest private house builder in Britain. Their book is a useful discussion on common problems caused by thermal and moisture movement, effervescence, decay of timber, deterioration of plaster and paintwork, sulphate attack and structural damp penetration. The examples are all relevant to house building.[10a.]

LITERATURE OF QUALITY CONTROL

GENERAL PRINCIPLES

13. Writers on industrial quality control make certain basic points. The more important of these are summarised here. Firstly, no manufactured article is ever perfect but for everything there is an acceptable degree of imperfection or tolerance which can be defined, either quantitatively by means of measurements, or in some other way. Secondly, in every industrial process there are

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10. T.H.McKaig. 'Field Inspection of Building Construction'. McGraw Hill, 1958.
10a. L.A. Ragsdale and E.A. Raynham. 'Building Material Practice'. Arnold. 1964

defects which constantly recur. One of the main objects of quality control systems is to distinguish between the few recurring defects in order that they may be eliminated and the many other defects which occur only rarely. The third point is that because an article has one or two defects, it is not necessarily a defective and worthy of rejection. It need only be rejected if the defects are serious or if they are so many that a total tolerance is exceeded.

COWAN: JURAN

14. Cowan's book 'Quality Control for the Manager' is a short, informal and very readable discussion of the basic ideas of quality control. It is easy to relate its examples to the house-building industry.[11] Deeper ideas on how to analyse defects and to evaluate their importance and the definition of tolerance are given in 'Quality Control Handbook' edited by Juran.[12]

LITERATURE OF CONSTRUCTION MANAGEMENT

SHEPHERD

15. The Shepherd report ('Construction Management in Building - Present and Future')[12a] identifies construction management as the central function in building. It makes an extensive analysis of the backgrounds of the men in charge of building sites and their responsibilities and proposes future training patterns.

16. The report identifies 'Control of Quality' as one of the responsibilities of site management and lists it as a sub-function of 'production'. The identification of the function of control of quality is welcome and it may be true that at present it is regarded as a sub-function

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11. Alan Cowan. 'Quality Control for the Manager'. Pergamon Press, 1964.

12. Ed. J.M. Juran. 'Quality Control Handbook'. 2nd Edition. McGraw Hill. 1962.

12a. 'Construction Management in Building: Present & Future'. The Institute of Builders. 1965.

of production, especially in private housing where there is no quality inspection by the client's agents. It is extremely questionable whether quality control should be linked so closely with production. The Report does not appear to recognise that production and quality inevitably conflict. The essence of production is to keep up a good speed of work and keep to programme or ahead of programme, whereas the essence of quality control is to examine what has been done and, if necessary, do it again. Quality should be regarded as equal and not subordinate to production. It will be argued later in this thesis that those responsible for quality inspection should report to a level of management above that responsible for day to day production.

LITERATURE OF BUILDING MARKETING

HOUSING RESEARCH FOUNDATION

17. The Housing Research Foundation has published two regional studies of the likes and dislikes of the purchasers of new houses. The regions studied are the South East and the West Midlands. Both reports identify slow after-sales service as the factor which most frequently causes purchasers to speak unfavourably about their builders. In the West Midlands, the proportion of purchasers making unfavourable comment was 50% and in the South East it was 53%. Those making favourable comments about speed of after-sales service were 31% and 32% for the two regions respectively. Purchasers were equally divided on whether they were satisfied with the quality of finish and the standard of workmanship in their houses. The study also gives data on the social classes or purchasers.[13]

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13. 'New Housing in South East England', and 'New Housing in the Midlands'. The Housing Research Foundation 1970 and 1971 respectively.

GREATER MILWAUKEE, U.S.

18. In 1966, the Metropolitan Builders Committee of Greater Milwaukee published definitive rules for deciding whether some common complaints were defects or non-defects within the terms of their new house warranty scheme. The rules covered small numbers of carpentry, plumbing and central heating items. The carpentry and plumbing items are reproduced in full as Appendix A, Schedule 1 of this thesis. The central heating items are not relevant to the types of installation used in British houses and are not reproduced.[14]

19. The carpentry rules indicate that dimensional criteria can be laid down for the levelness of floors, gaps and flushness. In plumbing, all leaks are classed as defects and mechanical breakdowns are not acceptable.

LOUISVILLE, U.S.

20. In all warranty schemes for new houses, including the N.H.B.R.C. scheme in Britain, the greatest risk from the builder's point of view is that the purchaser will regard routine maintenance work as building defects and bring forward a maintenance schedule at the end of the warranty period. The House Owners service policy offered by the House-Builders Association of Louisville distinguishes between items which are covered for the whole warranty period and those which are covered for lesser periods and those which are not covered at all. The warranty periods are shown in Table 1. The scheme is a fair one. The purchaser is covered against latent defects but the builder cannot be presented with a maintenance schedule.

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14. '<u>Registered Builder Standards</u>'. Metropolitan Builders Association of Greater Milwaukee, 1966.

ITEM	WARRANTY PERIOD
Latent defects	1 year
Dripping faucets Toilet adjustments	90 days
General maintenance	Only if reported in 60 days
Broken glass Minor defects in wall decoration	Only if reported on takeover of the house
Drive cracks due to ground movement. Concrete flaking due to de-icing salts. Shrinkage cracks in mortar or timber. Nail popping in plaster. Squeaking floors Gap between bath tube and tiling.	None

TABLE 1. WARRANTY PERIODS IN LOUISVILLE

UNPUBLISHED WORK OF THE N.H.B.R.C.

MINOR AND FINISHING DEFECTS

21. In 1965, Walls analysed 100 complaint cases and found, as shown in Table 2, that numerically finishing defects are the most important group. Within the generic term of 'finishes', Walls distinguished defects which were caused by inadequate fixing and jointing from those which were general poor workmanship with no functional defect.

DEFECTS	% OF ALL DEFECTS IN CASES
Major structural defects	0
Damp penetration and minor structural defects	13.3
Garages, paths, etc.	6.7
Finishes, including services	80.0
Total	100.0

TABLE 2. CASES ANALYSED BY WALLS IN 1965

STRUCTURAL DEFECTS

22. By 1970, Walls' picture had become out of date. It was known that there was a possibly increasing proportion of serious structural defects which, in terms of cost, were very important. Powell analysed cases, the cost of which had had to be met by N.H.B.R.C. under the terms of the Agreement because the builder had gone out of business or defaulted. It was found that 73% of the total cost was for structural defects, damp penetration and other serious items and only 27% for minor finishing defects. This was seen as the counterpart to Walls' results.

23. Also in 1970, Cooper made a particular study of subsidence and foundation failures because this was a costly field. There were major cases of subsidence or inadequate foundations but each of these was unique. Recurring items identified were the differential settlement of attached porches and garages and the settlement of ground floor slabs due to inadequate consolidation of the underfill.

REGIONAL VARIATION IN NUMBERS AND TYPES OF DEFECTS.

24. In 1969, Powell examined a small number of cases and found that the numbers of defects differed from region to region. This was due, in part, to differences in the numbers of damp penetration defects. It appeared that more defects occurred in the West than in the East and more in the South than in the North. The results of this work are shown in Table 3.

NUMBERS OF DEFECTS		
North West All Defects 52 (Damp) (14)	North East All defects 11 (Damp) (6)	Both North All defects 63 (Damp) (20)
West All defects 67 (Damp) (18)	East All defects 43 (Damp) (7)	Both Midland All defects 110 (Damp) (25)
South West All defects 61 (Damp) (12)	South East All Defects 70 (Damp) (10)	Both South All defects 131 (Damp) (22)
All West All defects 180 (Damp) (44)	All East All defects 124 (Damp) (23)	All All defects 304 (Damp) (67)

TABLE 3. REGIONAL VARIATIONS IN INCIDENCE OF DEFECTS (1)

REGIONAL VARIATION IN BUILDING QUALITY

25. In 1967, Area Supervisors from every part of the country carried out an exercise on one site in Berkshire to find out whether there was uniformity in the judgment of general quality of building. There was widespread agreement on what work was just barely acceptable. However, there was wide disagreement on what work was good. On analysis, it was found that staff from the North West gave a 'good' classification most frequently and staff from the South East least frequently. There was a consistent trend on a North West to South East gradient. From this it was concluded that standards were lowest in the North West and highest in the South East.

DEFINITION OF ACCEPTABLE SHRINKAGE

26. Under the terms of the Agreement, the builder is not required to make good normal minor shrinkage defects but by implication he is required to remedy excessive shrinkage defects. What is excessive? N.H.B.R.C. has worked on the basis that timber shrinkage in excess of $\frac{1}{4}$in. in 12in. is excessive in a non-centrally heated house and $\frac{3}{8}$in. in 12in. in a centrally heated house, with the proviso that any shrinkage which causes tongues to disengage is a defect whatever its extent. These are empirical rules but they do fit theoretical shrinkage factors for redwood. No rules have been established for assessing acceptable twist in woodwork or shrinkage in plaster.

ACCEPTABILITY OF CHIPPED BRICKS

27. N.H.B.R.C. has developed an empirical rule for deciding when the use of chipped bricks constitutes a defect. The rule is that any

individual chip larger than a 1p piece is unacceptable. Walls constructed of bricks with acceptable chips are acceptable provided that no more than 10% of the bricks in the wall appear to have chips when the wall is viewed from a distance of 15ft. or more.

IDENTIFICATION OF IMPORTANT DEFECTS

28. From time to time the N.H.B.R.C. has attempted to identify the most important defects in terms of frequency or cost as a basis for publications and builder education. In the absence of statistical data, the identification has had to be based on a concensus of subjective views. The following list was published in 1970.

Unprotected joinery causing excessive movement.

Badly compacted floor underfill causing slab settlement.

Dirty wall ties) causing damp penetration.
Misplaced vertical D.P.C.'s)

Inadequate bearings for lintols) causing structural failures.
Defects in roof framing)

Wavy plaster ceilings.

Rough brickwork.

Inadequate preparation for paint.

Bumpy floor tiling.

OTHER CURRENT RESEARCH

BRITISH BUILDING RESEARCH STATION

29. It is understood that the Building Research Station (B.R.S.) is currently analysing the technical enquiries it has received in recent years and the problems it has been asked to investigate.

The purpose of this enquiry is to identify important centres for the elimination of defects and failures. The enquiry relates to all types of building, including dwellings. The enquiry may be biased because it is possible that only the more obtuse or serious types of defects are referred to B.R.S. for advice.

SWEDISH BUILDING RESEARCH INSTITUTE

30. In 1966, the National Swedish Institute of Building Research started a feedback exercise on building defects and failures. Local authorities and others who encountered failures were asked to send details to the Institute. In time, the Institute hoped to achieve a national library of experience. Publications suggest that it is mainly the major structural type of problem which is reported to the Institute. The research is continuing.[15]

ACCURACY IN BUILDING IN BRITAIN

31. In 1969, the British Standards Institution published a draft for development on building accuracy. It is envisaged that after some years of trial and amendment, this document will form the basis of a code of practice on tolerances and accuracy in building. The building industry is, at present, testing the draft for feasability.[16]

32. The document relates mainly to setting out problems and tolerances and fits in component building rather than to the traditional techniques of house building. It does, however, include some proposed accuracy yardsticks and these are summarised in Table 4. The last item in the Table, $\frac{3}{8}$in. in 10ft. as a permissible deviation for floor and ceiling levels, is substantially more onerous than the $\frac{1}{4}$in. in 3ft. rule of thumb operated by N.H.B.R.C. staff. Either

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15. Axel Carlsson. 'Inventory of Defects and Damages to Buildings' The National Swedish Institute for Building Research. 1966.
16. '<u>Accuracy in Building</u>'. British Standards Institution. 1969.

N.H.B.R.C. is being too lenient or the B.S.I. draft is too stringent. No-one yet knows the standards of accuracy which are now actually being achieved. N.H.B.R.C. has also worked on a normal tolerance of $\frac{1}{8}$in. in 3ft. for deviation in detailed items, such as reveal margins.

ITEM	PROPOSED TOLERANCE
Straightness of brickwork	$\frac{1}{2}$in. in 20ft.
Verticality of brickwork	$\frac{3}{8}$in. in 10ft. subjec to a maximum of $\frac{1}{2}$in. in any load bearing wall.
Floor levels	$\frac{3}{8}$in. under a 10ft. straight edge.
Ceiling levels	

TABLE 4. B.S.I. PROPOSED TOLERANCES

PART II

METHOD

DATA COLLECTION

SOURCE OF DATA

33. As stated in the Introduction, the source of data for this research was the records of 1,000 case investigations made by N.H.B.R.C. officers. Complaints accepted as valid defects under the terms of the Agreement became 'defects' for the purposes of the investigation. In a very small proportion of cases, there was no N.H.B.R.C. opinion based on a site investigation. In such cases the disputes had been settled by correspondence. Judgment was used to distinguish between defects and non-defects, in these cases. Cases relating to Scotland, Northern Ireland, and to the 3rd-10th years of the ten year guarantee period were not included, thereby leaving as the source of data cases relating to the 1st and 2nd years of the guarantee period in England and Wales.

STAGES OF ENQUIRY

34. Firstly, factual data was obtained from case files entered on data sheets, coded and analysed in the computer. Secondly, a small number of additional manual tabulations were prepared to supplement the computer analyses.

NEED FOR SAMPLING

35. Because of the method of file storage and accessability, it was decided to study cases first reported in 1969 and for which the files had been closed during the period 1969-70. In the twelve months June 1969-May 1970, 2,800 case files were filed. Of these, some had first been reported in 1969 and were, therefore, eligible for study. A preliminary study showed that the number of defects in a case would be about 6. To analyse 2,800 x 6 defects would have been impossible and, in any case, unnecessary. It was, therefore, necessary to draw a representative sample of cases from the 2,800.

Advice on how to do this was obtained from the University staff and from the National Opinion Polls who had been engaged to do the computer work.

FIRST SAMPLING PLAN

36. The statisticians advised that the most sound method was to examine each of the 2,800 cases to see how many defects were contained in it. Cases would then be listed in counties starting with Northumberland and ending with Cornwall. Within counties, cases would be listed in descending order of the number of defects they contained. The object would then be to take as a sample the cases in which every nth defect occurred. The county listing would remove geographical bias. The difficult part was the calculation of n. A trial showed that the number of defect classes was likely to be 200 or more (in fact, it was 375). This confounded the theorists who said that with such a large number of defect types, a 100% sample was the only reliable one if one was to be sure at the end that the proportion of defects of each type was absolutely accurate. There was, in fact, no way of calculating a realistic n. But the analysis of all the 2,800 cases was impossible.

REVISED SAMPLING PLAN

37. Apart from volume of work, the first sampling plan was inappropriate for two other reasons. The first was that the 2,800 case universe was itself an artificial block sample of a continuous process. The second point was that the main object of the investigation was to identify the frequent defects and statistical inaccuracies in the incidence of the infrequent defects was of little real importance.

1,000 cases was a realistic number for analysis in the time available. The statisticians considered this investigation of a block of 1,000 cases would give as representative a picture of the whole universe for all years as it was possible to obtain. Therefore, files closed in September 1969 were examined and, after that, the files closed in October, November and December 1969 and in January, February and March, April and May 1971. In all, 1,028 cases were analysed. The extra 28 were included because the summary lists were grouped into regions and a complete list had to be taken to avoid regional bias.

DATA REQUIRED

39. It was decided that a coded data sheet would be needed for each defect. The primary piece of information required was the technical nature of the defect. Defects would need to be grouped into a realistic and representative number of classes.

The work described in paragraphs 24 and 25 had indicated that the geographical location of a defect was likely to be of interest. N.H.B.R.C. also wanted to know the type of builder responsible for defects. Therefore, the builder's registration number was required in order that details of him could subsequently be found. Some information was also desired on the cost of defects. Two further impressions had been formed. These were that defects could be divided into the technically significant and the trivial or non-significant and that the type of defect varied according to the number of defects in the case, singly reported defects being more structural or more serious than those forming complaints of 20 or 30 items. It also seemed sensible to include the building stage and trade to which the defect related. The case reference number would be required for reference purposes. After four trials, a data sheet was compiled as shown in Figure 2.

NOP/4436

ANALYSIS OF DEFECTS

Ser. No.

IDENTIFICATION OF DEFECT

Builders No:

(10)	(11)	(12)	(13)	(14)

Year: 1969 .... 1 (15)
1970 2

Case No:

(16)	(17)	(18)	(19)

Defect No:

(20)	(21)

No. of defects per case (on defect No. 1 only):-

Col.	Code
22	
23	
24	
25	
26	
27	
28	

DESCRIPTION OF DEFECT

(a) Location

Col.	Code
29	
30	
31	
32	
33	

(b) Stage (34)

Up to D.P.C. 1
D.P.C. to plate 2
Plate to roof completion...... 3
Roof to plaster completion...... 4
Plaster completion to house completion 5
External works 6

(c) Trade (35)

Ground/drains/ external works. 1
Brickwork 2
Carpentry (1st fixing) 3
Joinery.................... 4
Roofing 5
Plumbing 6
Engineering services 7
Plastering 8
Floorlaying 9
Painting 0

(d) Cost (36)

Less than £15 1
£15 - £100 2
More than £100 3

(e) Significance (37)

Not significant 1
Significant 2

TECHNICAL NOTES ....
....
....
....
....
....
....

CLASSIFICATION OF DEFECT

COL.	CODE	

FIGURE 2. DATA EXTRACTION SHEET.

DATA ON COSTS

41. The allocation of a cost to each defect was a matter of judgement and not of fact. Only rarely is the cost of remedying a defect known to N.H.B.R.C. As can be seen from the data sheet, three cost categories were chosen. The first category of under £15 was the one that N.H.B.R.C. was considering using as an excess value in cases where it had to meet the cost of remedial works due to the builder's bankruptcy. The top category of £100 or more was selected to identify the comparatively few very costly defects. Strictly speaking, these figures are an estimate of what the remedial work would cost the builder of the house (i.e. nett cost) and not what would necessarily be charged by an outside builder.

SIGNIFICANCE OF DEFECTS

42. Part way through the analysis, it became clear that this was an erroneous concept. The criteria used for deciding that a defect was significant were that there was risk to the building, risk to persons, non-provision or non-functioning of a component, an excessive amount of a non-significant defect or workmanship that would be unacceptable to most people. It was felt that these were not the right criteria because too many subjective judgments were having to be made. For consistency, a classification was given to each defect and the results analysed. They are not, however, given in the thesis. A four-part seriousness classification was substituted at a later date and found to be more appropriate.

GEOGRAPHICAL DATA

43. The county was selected as the geographical location information to be included in the data. Other possibilities were towns, regions or areas. The towns were obviously too small and diffuse units to

use for analysis purposes. It was envisaged that regions would be used for comparative purposes because they contain identical numbers of new houses. However, the purpose of geographical analysis was to try to explore the effects of climate and an N.H.B.R.C. region is so large that it could experience almost every climatic variation. If counties were used, they could easily be grouped up into regions in the computer as regional and county boundaries are coincident. Other groupings of counties could also be made to create further groups of like counties. At this stage, areas were discounted because an area is an artificial unit cutting across county boundaries. The allocation of an address to an area is laborious and involves the use of maps and gazetteers. It will be shown later in the thesis that an allocation of areas had to be made in the end in order to establish any order in overall patterns of defect incidence. The county was inappropriate for this latter purpose because the number of houses in a county varies. Areas, on the other hand, like regions, have virtually equal numbers of houses in them.

44. Climatic factors which could possibly influence the rate of damp penetration and drying out defects would be rainfall, wind speed and humidity. The Building Research Station driving rain index map (Figure 3) was examined and groups of counties selected for high rainfall/wind speed index and low rainfall/wind speed index. Groups of coastal and non-coastal counties were also selected for investigation.

DEFECT CLASSIFICATION

45. The hardest part of the enquiry stage was deciding how to record and group up the data on the nature of defects. There were two conflicts.

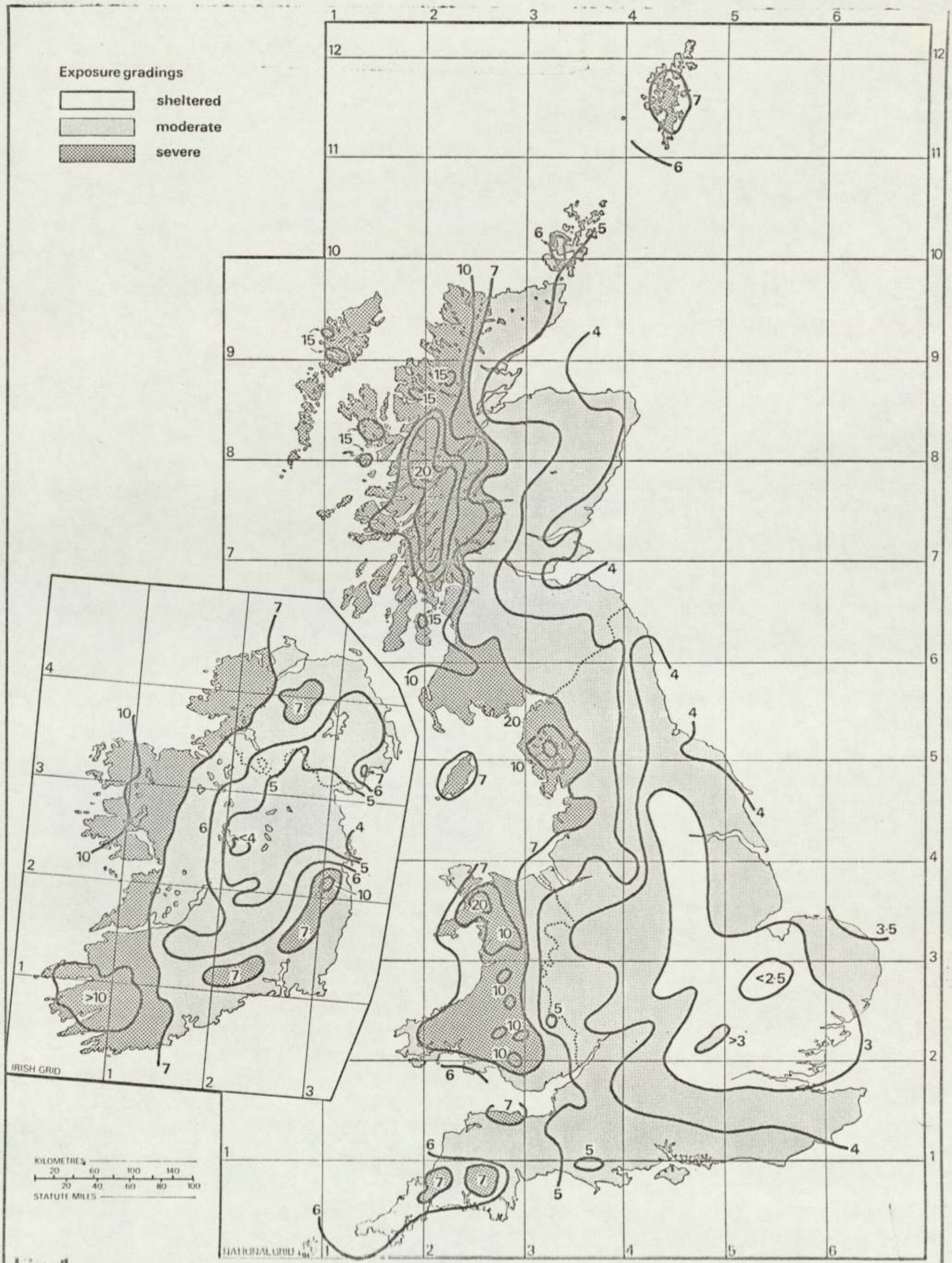

FIGURE 3. BRS DRIVING RAIN INDEX MAP.

The first conflict was on degree of detail. It was known that there were at least 200 different types of defects. On the punch cards it would be possible to analyse 400 different types and twice that number by using a second card. But the use of large numbers of categories would make the data so diffuse as to be incomprehensible.

The alternative was to select a small number of large scale categories. This, however, would sacrifice much detail that was available, easy to record and likely to be of considerable future use. The answer was to use main categories for analysis work and sub-categories to give the richness of detailed information that was available. It was, therefore, decided to use the maximum number of sub-categories and 375 out of the 400 available were used. A sub-category is counted only once for every house, even though that particular defect may occur more than once in the house.

46. The second problem was to decide the nature of the main categories. Classification by building elements would be easy, e.g. foundations, windows, plumbing, etc., and would probably be quite illuminating. Previous work had shown (paragraphs 21 to 24) that other main categories were possible. Examples of these were damp penetration, inadequate fixings and structural. These would cut across classication by elements. For example, windows could have damp penetration defects, fixing defects or shrinkage defects. The problem with using family groups such as these was that a comprehensive system had not been established and could not be established until the data had been extracted. It was, therefore, decided to group the sub-categories into main categories according to building element for computer count and to re-group them afterwards into defect groups which would include structural, damp penetration, fixings and shrinkage. It will be shown subsequently in the thesis that the groups were the most useful for comparative work.

47. The selection of sub-categories, or individual defect classes, had to be undertaken in two stages. At the stage of extracting data from files, it was not known what classes would give the most beneficial use of the 400 classes available on one punched card. To minimise mistakes, the information about the defects in 500 cases was put on to data sheets before any classifications were selected. The sheets were examined and hand sorted and a set of classifications and codes built up. For the next 250 cases, a simplified method was possible, omitting the hand sorting. The defects in the final 250 cases were coded direct without written information being entered on the data sheets.

COMPUTER ANALYSES

48. Data from the sheets were transferred on to punch cards and analysed in the computer to give the following tables. Data were percentaged to facilitate the observation of comparative frequencies.

(1) Class of defects by region.

(2) Class of defect - cases consisting of only one defect by region.

(3) Class of defect x 5 counties of high rainfall/windspeed and 5 counties of low rainfall/windspeed.

NOTE:

High rainfall counties - Cheshire, Cornwall, Devon, Glamorgan, Lancashire.

Low rainfall counties - Essex, Greater London, Kent, Northants, Surrey.

(4) Class of defect x 3 coastal counties and 3 inland counties

NOTE:

Coastal - Devon, Glamorgan, Sussex.

Inland - Nottingham, Surrey, Warwick.

(5) Class of defect by trade.

(6) Class of defect by cost.

(7) Class of defect by stage.

(8) Cross analyses of cost, stage and trade.

(9) Number of defects per case by region.

(10) Number of cases and number of defects per builder per region.

RESPONSIBILITY FOR DEFECTS

49. Defect classes were re-sorted manually into four main responsibility categories. These were designer/site supervision/workmanship/material and component suppliers. The analysis was done for all defects and for the more serious type of defect constituting single defect cases. The criteria used will be given later in the thesis.

FACTS ABOUT BUILDERS

50. The builder's registration number was included in the computer data and, therefore, individual builders and the number of cases in which they were involved could be identified. Amongst the things known by N.H.B.R.C. about a builder are whether or not he trades as a limited company, the number of houses he builds in a year and the date upon which he became a registered house-builder and, therefore, had to undertake to remedy defects in his houses. The number of defects and the number of cases were sorted by builder size and builder registration period. Other data about a builder was gleaned from general files. The gleaning exercise was done for builders identified as having defects in this sample and for a control.

CLASSIFICATION FOR SERIOUSNESS

51. As stated in paragraph 42, the computed seriousness classification was found unsatisfactory. In stage 2, a manual re-analysis of defect classes was made into four categories which were very serious (structural), other very serious, less serious and not serious. A system of demerit ratings for each of the four groups was devised according to normal

quality control practice.

UNJUSTIFIED DEFECTS

52. An investigation was made into alleged defects which were not found justified by N.H.B.R.C. Investigating Officers. The purpose of this investigation was to help identify the demarcation lines between defects and non-defects.

PART III

RESULTS

THE INCIDENCE OF DEFECTS

THE DATA RELATED TO ALL DEFECTS

RATE OF COMPLAINT TO N.H.B.R.C.

53. The number of cases settled by N.H.B.R.C. in the twelve months June 1969-May 1970 was 2,800 (paragraph 35). These cases relate to houses completed and issued with their guarantee certificates in the preceding two years. The annual number of houses completed and guaranteed in the relevant period was about 140,000. Therefore, the proportion of complaints to guarantees issued was:

$$\frac{2,800}{140,000} \times 100 = 2\%$$

This means that only 2% of house purchasers made a substantive complaint to N.H.B.R.C. The remaining 98% were assumed to have been satisfied by their builders.

REMEDIAL COST OF DEFECTS IN SAMPLE

54. The 1,028 cases analysed in this research contained 5,372 defects. The cost estimates for these defects were as shown in Table 5.

ESTIMATE COST GROUP	DEFECTS IN GROUP	
	NO.	%
Under £15.00	4,215	78.4
£15 - £100.00	1,023	19.0
Over £100.00	104	1.9
TOTAL	5,372	100.0

TABLE 5. COST GROUPS OF DEFECTS

To estimate the total cost of the defects in the 1,028 cases, it is necessary to assume mean costs for defects in each cost group. There is no way of ascertaining such values except by subjective judgment. It seemed reasonable to take £8.00, £50.00 and £300.00 as means for the respective groups. On this basis, the remedial cost of defects in these 1,028 cases is:

4,215	x	£8.00	=	33,720
1,023	x	£50.00	=	51,150
104	x	£300.00	=	31,200
	Total			£116,070

It follows that the cost per case is $\frac{£116,070}{1,028}$ = £113.00 per case.

" " " " " " defect = $\frac{£116,070}{5372}$ = £20.00 " defect

UNKNOWN EXTENT OF DEFECTS

55. Figure 4 illustrates the point that of all defects in new houses, only a proportion will contain any one particular defect and only a small proportion of these defects will reach, and be justified, by the N.H.B.R.C. This proportion may be expressed as:

$$P = P_d \times P_o \times P_a \times P_r \times P_n \times P_c \times P_j$$

where P_d is the proportion of houses with any particular defect, P_o the proportion of purchasers who observe the defect, P_a the proportion of lay purchasers who appreciate the defect, P_r the proportion of purchasers who report the defect to the builder, P_n the proportion of occurrencies in which the builder does not remedy the defect, P_c the proportion of unremedied defects notified to the Council and P_j the proportion of reported defects found justified by the Council.

QUALITATIVE VALUE OF DATA

56. It has been shown that the data upon which this thesis is based is

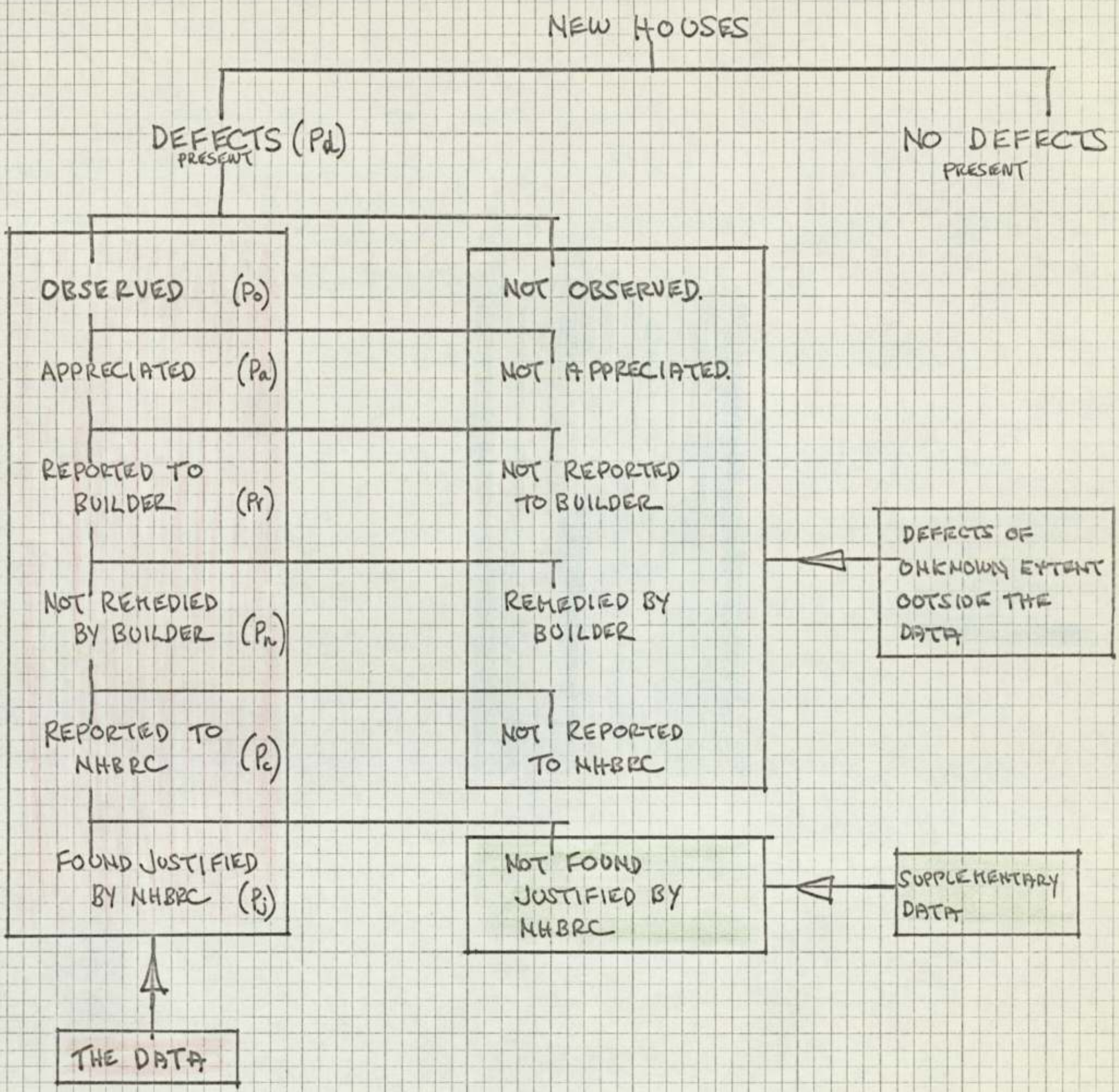

FIGURE 4. THE DATA IN RELATION TO ALL DEFECTS.

quantatively only the tip of a large iceberg whose size cannot be estimated. The next question is 'Are the data representative of the types of defect that exists in the hidden part of the iceberg?'. The answer is not known. However, it can be argued with reasonable confidence that the data are typical of the types of defects observed by purchasers and remedied by builders.

UNRECOGNISED AND HIDDEN DEFECTS

57. There is good evidence that the data are not typical of the defects which are present in houses but which are not perceived by the purchaser. The purchaser, as a layman, will not necessarily recognise or be offended by all the visible defects. N.H.B.R.C. Investigating Officers often comment wryly on items that the purchaser could have brought forward as complaints but for reasons known only to himself, did not. What is more serious is the number of hidden defects in the structures of houses which never come to light. N.H.B.R.C. Inspectors inspecting houses during construction find 28-30% of all faults in the superstructure brickwork . In this research, only 7% of defects are in brickwork. The difference is likely to be due not to the fact that brickwork defects do not exist, but that they are not seen and appreciated by the lay purchaser. Forbes of the Building Research Station found that 27% of man hours in private house construction were for brickwork.[17] If it is accepted that defect incidence must to some extent be proportional to man hours expended, this confirms the argument based on the N.H.B.R.C. figures.

58. This leads to a philosophical argument. It can be argued that if a defect exists and is not perceived, or if it is hidden and does not reveal itself by giving rise to damage, then it is of no consequence. On the other hand, the purist will argue that because it exists, it

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17. W.S. Forbes. '<u>A survey of progress in house-building</u>'. Building Technology and Management. April 1969.

must be considered as part of the total sum of defectiveness in new houses. Perhaps the most realistic course is to base one's judgment on the degree of risk. What is the probability of the defect being perceived? What is the probability of it revealing itself by causing damage? At present, the unrecognised hidden defects are not critical, but if their proportion relative to all defects were to increase and become nearer the proportion of man hours spent, this would be evidence of declining standards and a critical state of affairs being reached.

DATA ARE REPRESENTATIVE

59. The conclusion of these arguments is that the data are not representative of the correctness or otherwise of building construction but they are representative of defects that are recognised and give rise to damage or dissatisfaction to the purchasers of new houses.

GENERAL PATTERNS OF DEFECT INCIDENCE

ELEMENT, STAGE, TRADE AND COST

60. Tables 6-11 summarise the computer counts and show the proportions of defects allocated to building elements, stages of building, building trades and the three cost groups. The main points from these tables are shown in Figures 5-8. Figure 5 shows that most occur in the joinery trade. Joinery accounts for 28.1% of all the defects and joinery elements for 29.1%. This largely due to the incidence of movement defects (shrinkage, twist, etc.) which will be discussed later in the thesis. Figure 6 shows that most defects occur in the late stages of building, that is from roof completion onwards. These are, of course, the most visible defects. However, Figure 7 shows that of the defects estimated at a £100 or more remedial cost, most occur in the early foundation and structural stages. Figure 8 the pie chart, illustrates the numerically high proportion of low cost

defects and the numerically small proportion of high cost ones. This, however, must be interpreted in the light of the relative total costs already given in paragraph 54 where the few high cost defects are as important in total as the many low cost ones.

61. The situation can be summarised by saying that few of the reported defects occur in the early groundwork and structural stages of building but those that do are often of high remedial cost. The majority occur in the later stage or are caused by movement in later stage components and are of low remedial cost.

HOW MANY DEFECTS PER CASE

62. The data consists of 1,028 cases having between them 5,372 individual defects, or more precisely defect class/cases. Therefore, the mean number of defects per case is:

$$\frac{5,372}{1,028} = 5.2$$

A histogram of the distribution of numbers of defects per case is shown in Figure 9. Just under 30% of cases consist of only one defect. There is a steady fall in the proportion of cases as the number of defects increases from two to eighteen. 95% of the cases have eighteen or fewer defects. After eighteen defects, the trend continues up to thirty-four defects, by which time, 98.6% of the cases have been included. After thirty-four defects, the pattern is irregular up to a maximum of fifty defects per case.

ELEMENT	% OF ALL DEFECTS	
Substructure	1.8	
Brickwork and Blockwork	7.0	
First Fixings	3.3	
Roof coverings	6.3	
Rainwater disposal	2.1	
Chimneys and flues	2.2	
Windows	6.8	28.1 total joinery
External doors and frames	7.1	
Internal doors and linings	6.2	
Floor boards and skirtings	3.4	
Staircases	2.4	
Other joinery	2.2	
Internal plumbing	8.0	
Engineering services	5.4	
Plastering and wall tiling	11.1	
Floor finishes	3.2	
Glazing and external paintwork	4.8	
Internal decoration	3.9	
Garages	5.0	13.4 total external works
Drives and paths	4.6	
Drainage	2.2	
Other external works	1.6	
	100.0	

TABLE 6. PROPORTION OF DEFECTS BY ELEMENTS

STAGE	% OF ALL DEFECTS
Up to DPC	2.5
DPC - plate	16.4
Plate - roof completion	10.6
Roof completion - plaster completion	23.2
Plaster completion - house completion	39.1
External works	6.7
	100.0

TABLE 7. PROPORTIONS OF DEFECTS BY STAGES.

TRADE	% OF ALL DEFECTS
Ground work and concrete	7.8
Brickwork and blockwork	11.3
Carpentry (first fixings)	3.5
Joinery	29.1
Roof covering and rainwater disposal	9.6
Plumbing	7.9
Engineering services	5.7
Plastering	11.4
Floor finishing	3.3
Painting and decoration	9.2
	100.0

TABLE 8. PROPORTION OF DEFECTS BY TRADES

ELEMENTS	% OF ALL DEFECTS			
	COST GROUPS			
	Under £15	£15 - £100	£100+	
Substructure	0.6	3.5	32.7	
Brickwork and blockwork	5.5	12.8	14.4	
First fixings	3.1	3.5	11.5	
Roof coverings	6.3	6.6	3.8	
Rainwater disposal	2.5	0.6	-	
Chimneys and flues	1.5	5.0	3.8	
Windows	7.5	4.6	-	
External doors and frames	8.4	2.2	-	
Internal doors and linings	7.4	2.0	-	
Floorboards and skirtings	3.8	1.7	1.0	
Staircases	2.6	1.9	-	
Other joinery	2.6	0.8	-	
Internal plumbing	9.0	4.7	-	
Engineering services	5.4	5.2	5.8	
Plastering and wall tiling	11.3	10.6	4.8	
Floor finishes	2.8	4.8	5.8	
Glazing and external paintwork	5.2	3.8	-	
Internal decoration	4.6	2.0	-	
Garages	4.8	5.8	2.9	17.3
Drives and paths	1.9	10.2	5.8	
Drainage	1.9	4.0	1.9	
Other external works	1.0	3.7	6.7	
	99.7	99.0	100.9	

TABLE 9. PROPORTIONS OF DEFECTS BY ELEMENTS BY COSTS

STAGE	% OF ALL DEFECTS		
	COST GROUPS		
	Under £15	£15 - £100	£100+
Up to DPC	1.0	5.0	35.0
DPC - plate	14.0	26.0	28.0
Plate to roof completion	11.0	9.0	3.0
Roof completion - plaster completion	23.0	24.0	17.0
Plaster completion - house completion	46.0	18.0	4.0
External works	5.0	18.0	13.0
	100.0	100.0	100.0

TABLE 10. PROPORTIONS OF DEFECTS BY STAGES BY COSTS.

TRADE	% OF ALL DEFECTS		
	COST GROUPS		
	Under £15	£15 - £100	£100+
Ground work and concrete	5.0	20.8	42.2
Brickwork and blockwork	8.5	21.4	23.1
Carpentry (first fixings)	3.2	3.9	11.5
Joinery	33.9	12.7	1.0
Roof covering and rainwater disposal	9.8	9.1	3.8
Plumbing	8.9	4.7	1.0
Engineering services	5.7	6.1	5.8
Plastering	11.9	10.4	5.8
Floor finishing	2.8	5.0	5.8
Painting and decoration	10.3	5.9	-
	100.0	100.0	100.0

TABLE 11. PROPORTIONS OF DEFECTS BY TRADES BY COST.

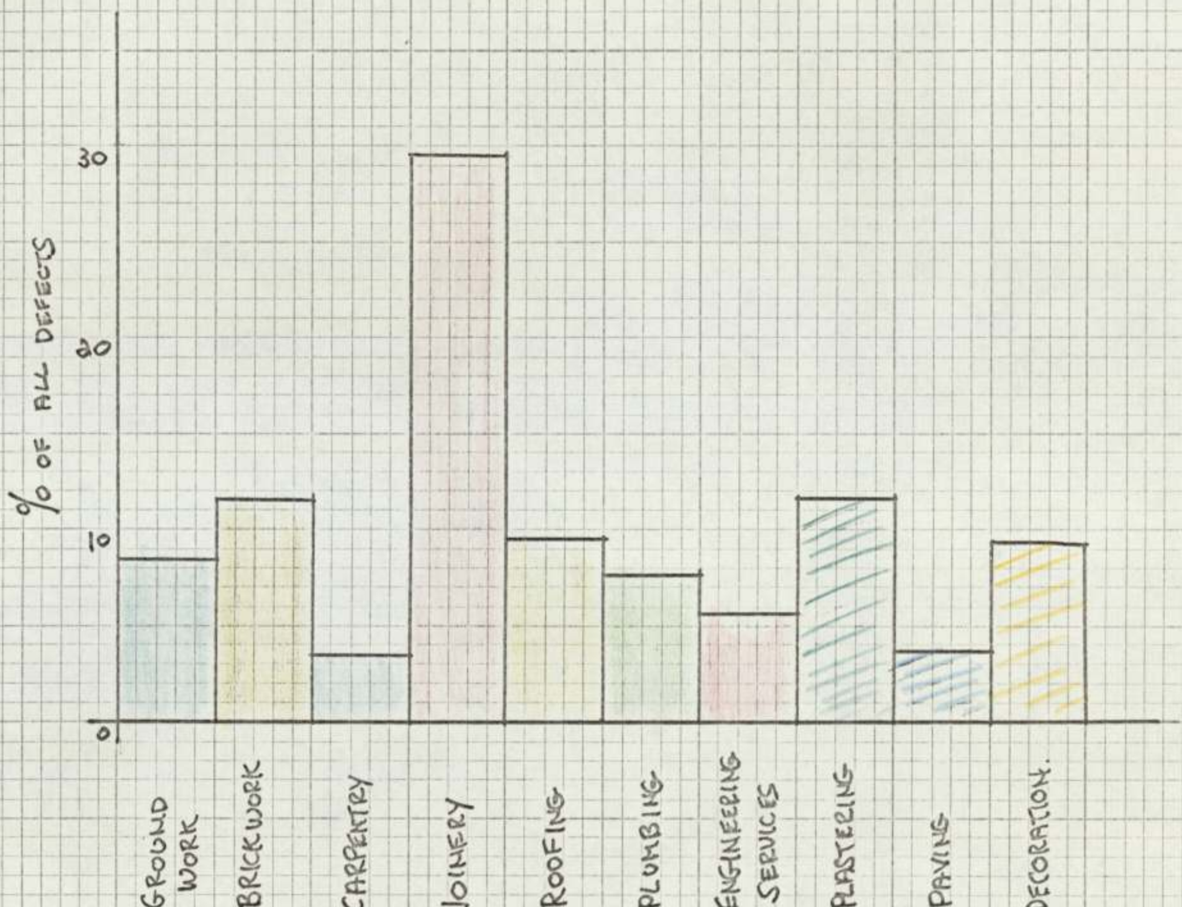


FIGURE 5. PROPORTIONS OF DEFECTS BY TRADES.

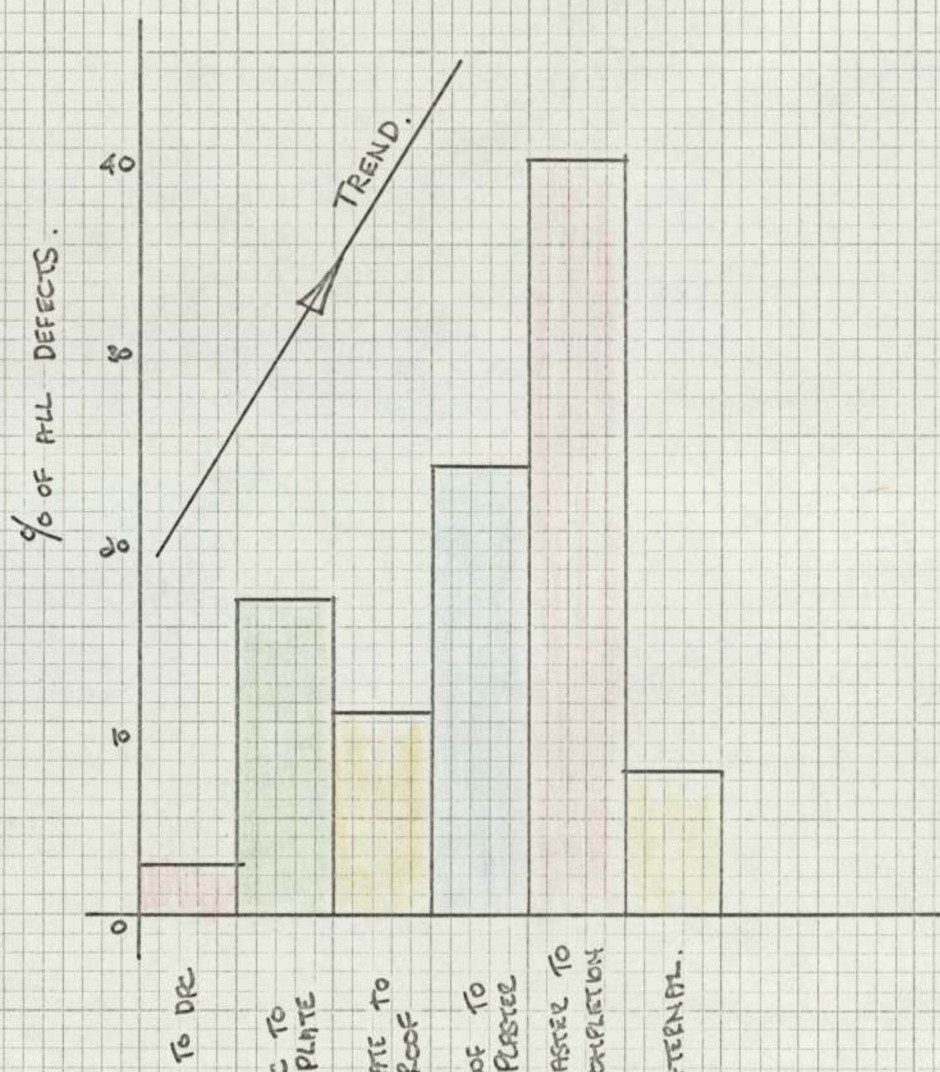


FIGURE 6. PROPORTIONS OF DEFECTS BY STAGES.

FIGURE 7. PROPORTIONS OF HIGH COST DEFECTS BY STAGES.

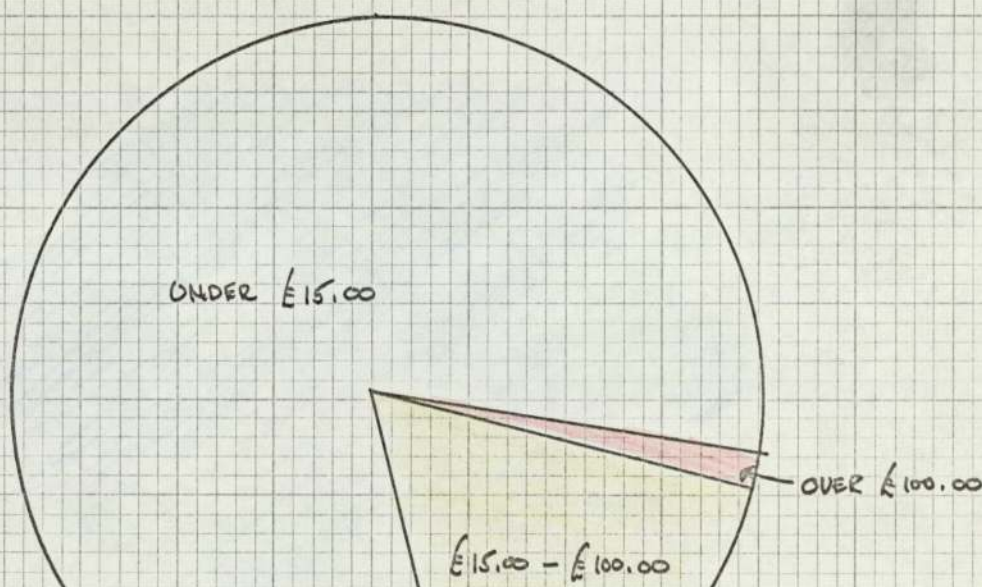


FIGURE 8. PROPORTIONS OF DEFECTS BY COST GROUPS.

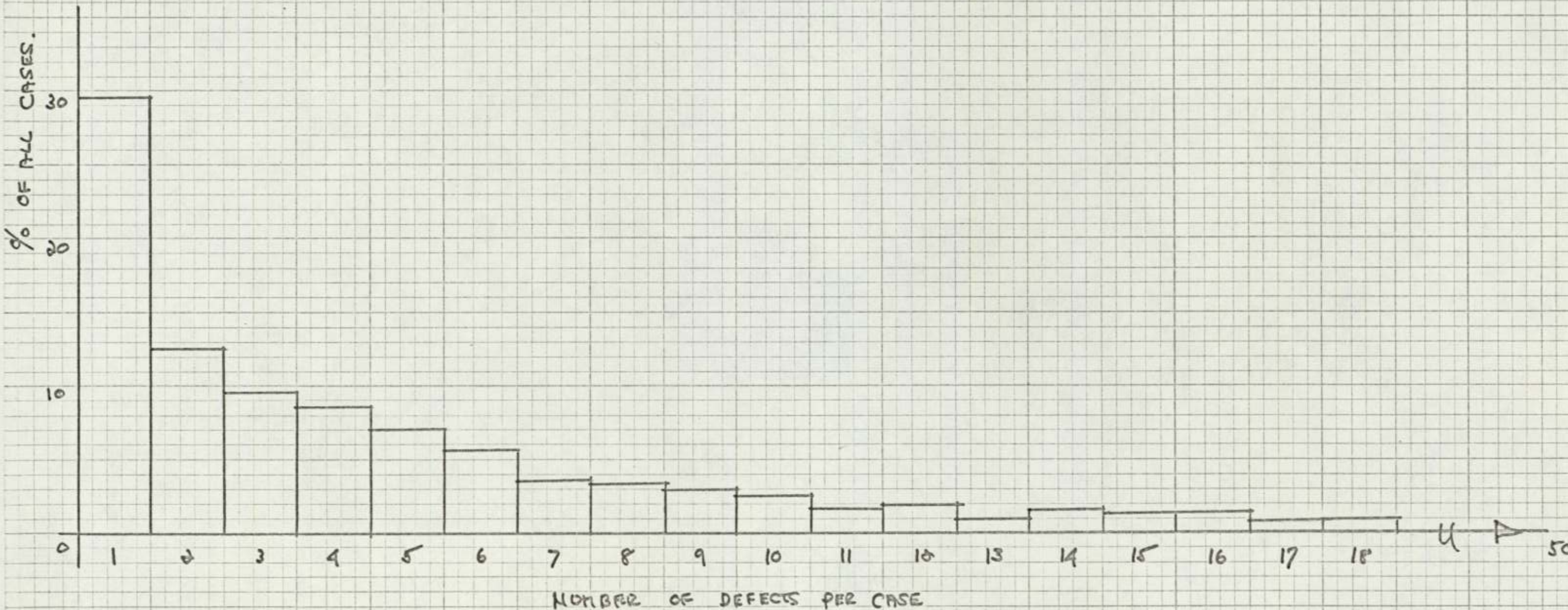
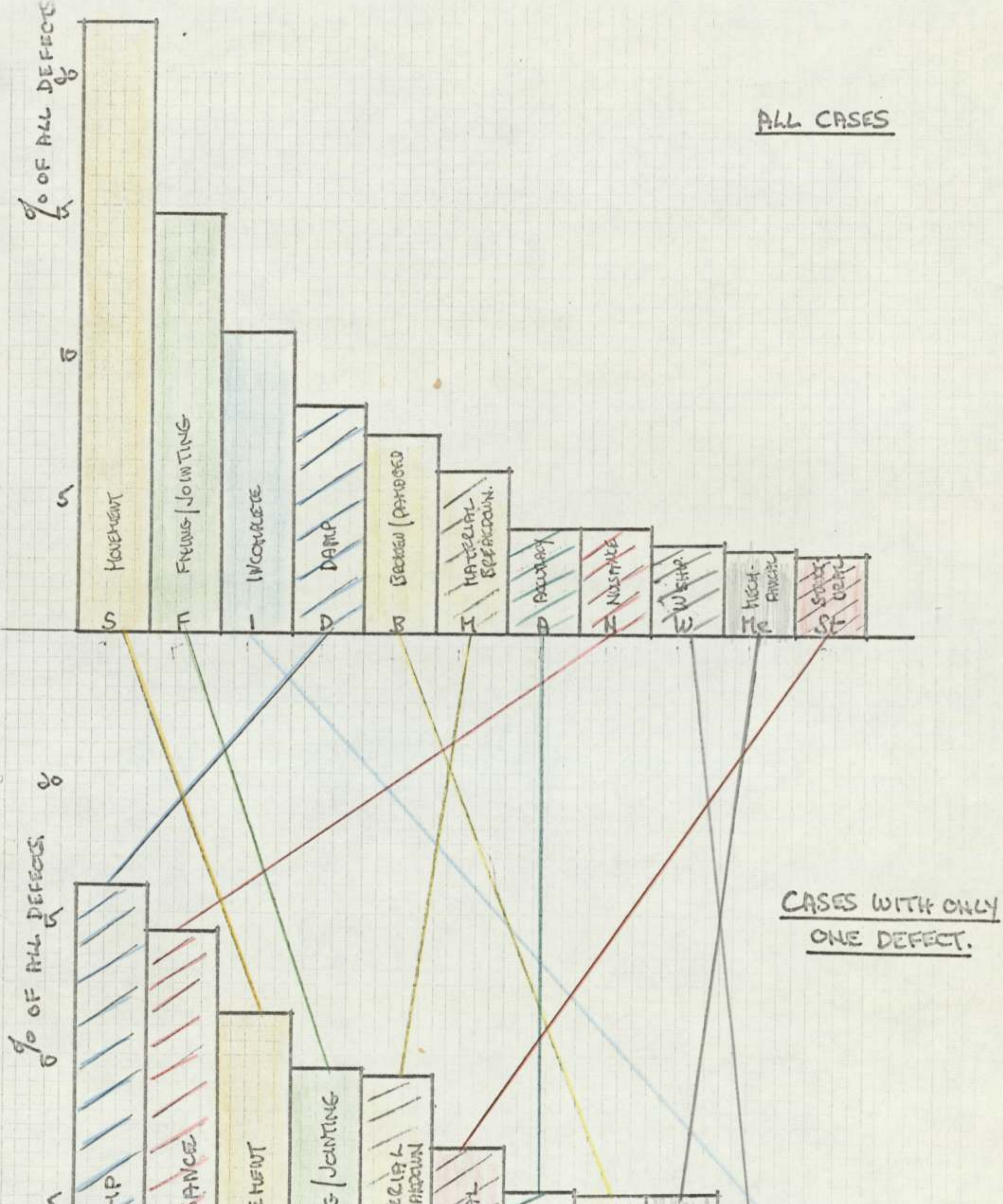


FIGURE 9. PROPORTIONS OF CASES BY NUMBERS OF DEFECTS PER CASE.



A - ACCURACY. B - BROKEN/DAMAGED. D - DAMP PENETRATION F - FIXING/JOINTING
I - INCOMPLETE M - PREMATURE MATERIAL BREAKDOWN. Me - MECHANICAL
N - NUISANCE/HEALTH/SAFETY S - BUILDING MOVEMENT. St - STRUCTURAL
W - GENERAL WORKMANSHIP

FIGURE 10. DEFECT GROUPS BY NUMBERS OF DEFECTS IN CASES.

REGIONAL INCIDENCE

63. Table 12 shows the number of cases and number of defects analysed into the six N.H.B.R.C. regions. The pattern is consistent with that noted earlier in paragraph 24 and Table 3 , i.e. the numbers of cases and defects increase from East to West and from North to South. The East to West trend is accounted for, to some extent, by the damp penetration defects.

NUMBERS OF CASES AND DEFECTS					
North West		North East		Total North	
Cases	174	Cases	125	Cases	299
Defects	997	Defects	528	Defects	1525
Damp defects	120	Damp defects	46	Damp defects	166
West		East		Total Midland	
Cases	195	Cases	150	Cases	345
Defects	920	Defects	775	Defects	1695
Damp defects	83	Damp defects	47	Damp defects	130
South West		South East		Total South	
Cases	206	Cases	178	Cases	384
Defects	1121	Defects	1031	Defects	2152
Damp defects	95	Damp defects	41	Damp defects	136
Total West		Total East		Total	
Cases	575	Cases	453	Cases	1028
Defects	3038	Defects	2334	Defects	5372
Damp defects	298	Damp defects	134	Damp defects	432

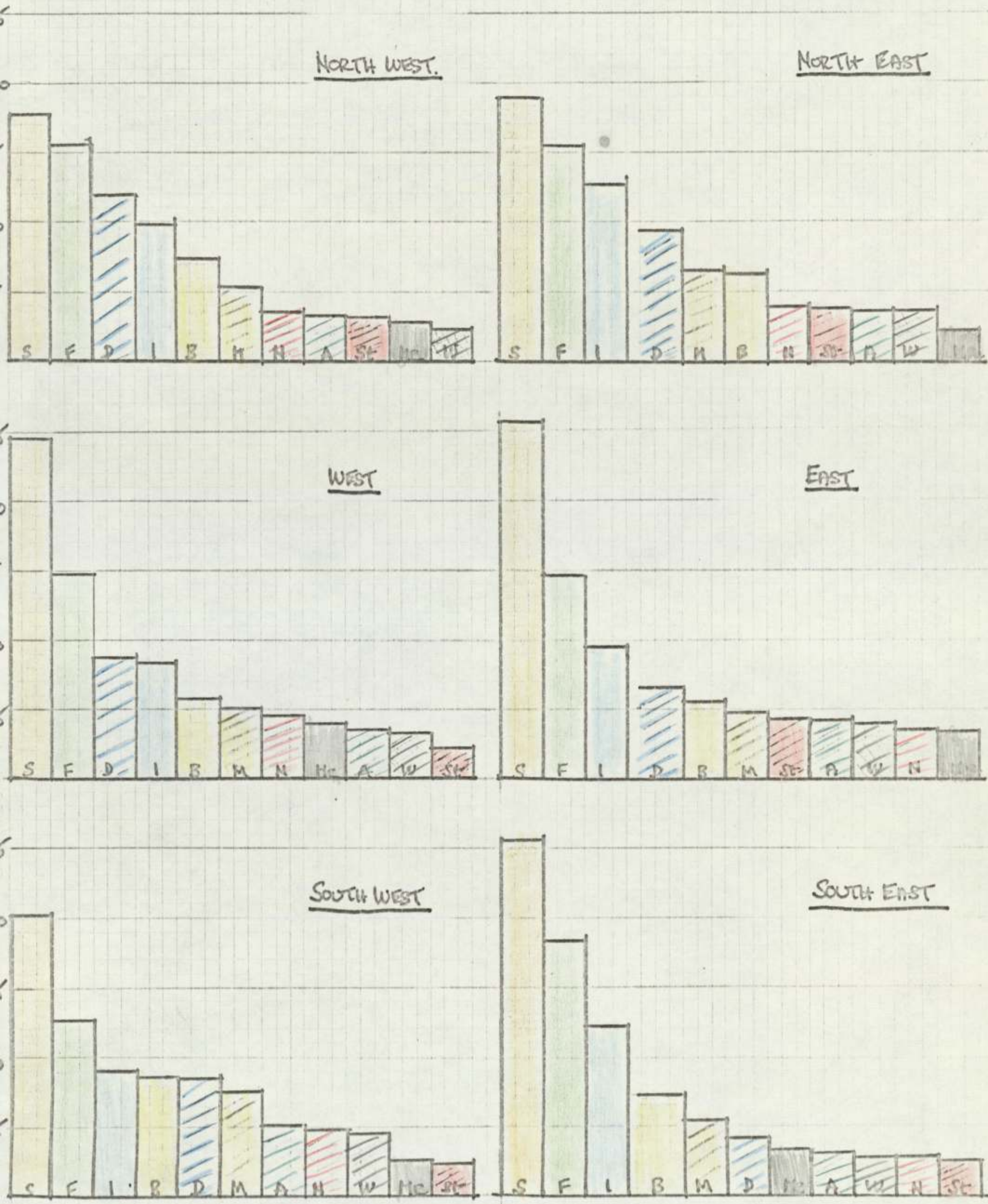
TABLE 12. REGIONAL VARIATIONS IN INCIDENCE OF DEFECTS (2)

DEFECT GROUPS

64. It was explained in paragraph 47 how the main groupings of defects were decided upon. The computer tables were prepared with building elements as the main categories and subsequent manual re-analysis was carried out to build up defect groups based on the attributes of the defects. The classification shown in Table 13 was adopted. This allocates each defect to one of eleven defect groups. Table 13 also shows the proportions of defects in each group, for defects from all cases, defects from cases having only one defect and defects from cases having 12 or more defects. The last category contains only some 100 cases but 25% of all the defects. Figure 10 shows how the serious type of defects relating to critical building functions predominate in the one defect cases and the least technically serious types in the cases with twelve or more defects. The defect group for each defect class is given in Appendix B.

DEFECT GROUP		% DEFECTS IN EACH GROUP		
		1 defect cases	All defect cases	Over 12 defects cases
Critical building functions	Structural inadequacy	6.8	3.0	2.4
	Damp penetration	16.3	8.7	5.0
	Inadequate mechanical parts	5.1	3.3	2.3
	Inadequate fixings and jointing.	9.5	14.8	17.2
	Premature breakdown of materials.	9.3	9.3	5.9
Personal risk	Nuisances and safety and health risks	14.4	4.1	3.5
Contractual matters	Non-provision of items required under the Agreement and incomplete work.	4.1	11.3	11.8
	Failure to replace goods damaged or broken by the builder.	5.4	7.5	9.2
Matters of tolerance	Initial building movement in excess of normal tolerances.	11.5	21.5	21.2
	Building functionally adequate but out of normal accuracy tolerances.	5.2	3.7	3.8
	Workmanship functionally adequate but of unacceptable general standard.	2.5	3.2	3.1
		90.1	90.4	85.4
	Defects whose class is 'various' or related to more than one group.	9.9	9.6	14.6
		100.0	100.0	100.0

TABLE 13. PROPORTIONS OF DEFECTS BY DEFECT GROUPS.



KEY AS FOR FIGURE 10.

FIGURE 11. DEFECT GROUPS BY REGIONS.

DEFECT GROUPS AND REGIONS

65. Figure 11 shows the distribution of defects by defect groups for each region. It is immediately apparent that initial movement and inadequate fixings are the most numerous groups in all regions. Proportionally, they account for more defects in the East and South East. As might be expected, damp penetration ranks high in the North West and West and low in the South East.

DEFECT GROUPS AND CLIMATIC ENVIRONMENT

66. As stated in paragraph 44 , defects occurring in groups of counties of high rainfall/windspeed and low rainfall/windspeed and groups of coastal and non-coastal counties were compared. Table 14a and Figure 12a show that damp penetration accounts for 13.6% of defects in Cheshire, Cornwall, Devon, Glamorgan and Lancashire and for only 5.3% in Essex, Greater London, Kent, Northants and Surrey. In the case of the coastal group of counties, Devon, Glamorgan and Sussex and the non-coastal group of Nottingham, Surrey and Warwick, damp penetration accounts for 11.2% and 6.6% of defects respectively. In the high and low rainfall groups, the differences for damp through walls, damp through roofs and damp through joinery are uniform but in the coastal comparison, the difference between roofs is less marked but there is a very high rate of damp entry through walls and joinery. It would, therefore, appear that damp penetration of vertical building elements is a coastal phenomenon.

67. Table 14b and Figure 12b indicated that movement, i.e. shrinkage and twist, defects are relatively more common in the drier counties than in the humid.

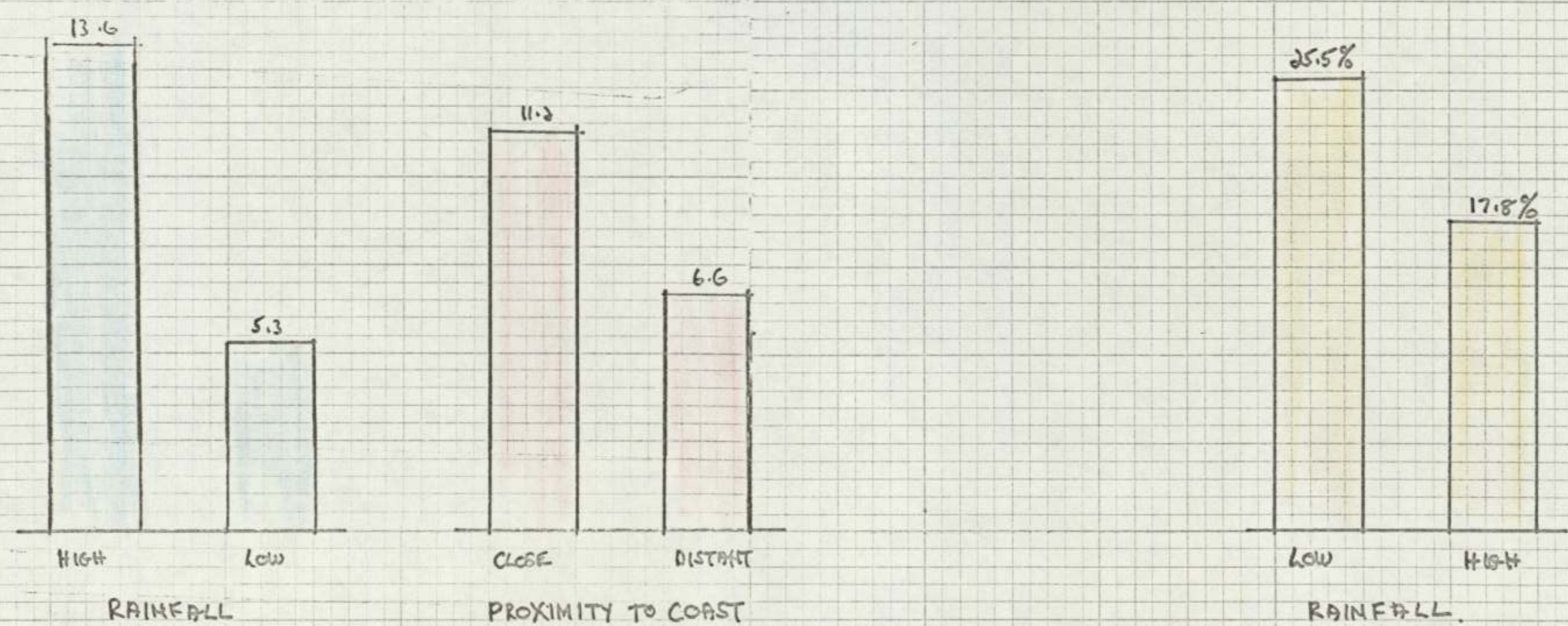
% OF ALL DEFECTS DUE TO DAMP PENETRATION				
ELEMENT	Rainfall/Windspeed		Coastal	
	High	Low	Coastal	Non-coastal
Foundations and walls	5.2	1.1	4.2	1.0
Roofs	5.1	2.0	3.1	3.0
Joinery	3.3	2.2	3.9	2.6
Total	13.6	5.3	11.2	6.6

(a) DAMP PENETRATION

% OF ALL DEFECTS DUE TO INITIAL MOVEMENT		
	Rainfall/Windspeed	
	High	Low
Joinery	10.6	12.8
Carcassing	0.2	1.4
Brickwork	0.4	1.9
Plastering, rendering and floorscreeds	6.6	9.4
Total	17.8	25.5

(b) INITIAL BUILDING MOVEMENT

TABLE 14. COUNTY GROUP COMPARISONS.



(a) PROPORTIONS OF DEFECTS DUE TO DAMP PENETRATION.

(b) PROPORTIONS OF DEFECTS DUE TO INITIAL MOVEMENT OF BUILDING

FIGURE 12. COUNTY GROUP COMPARISONS.

DEFECT INCIDENCE BY AREAS

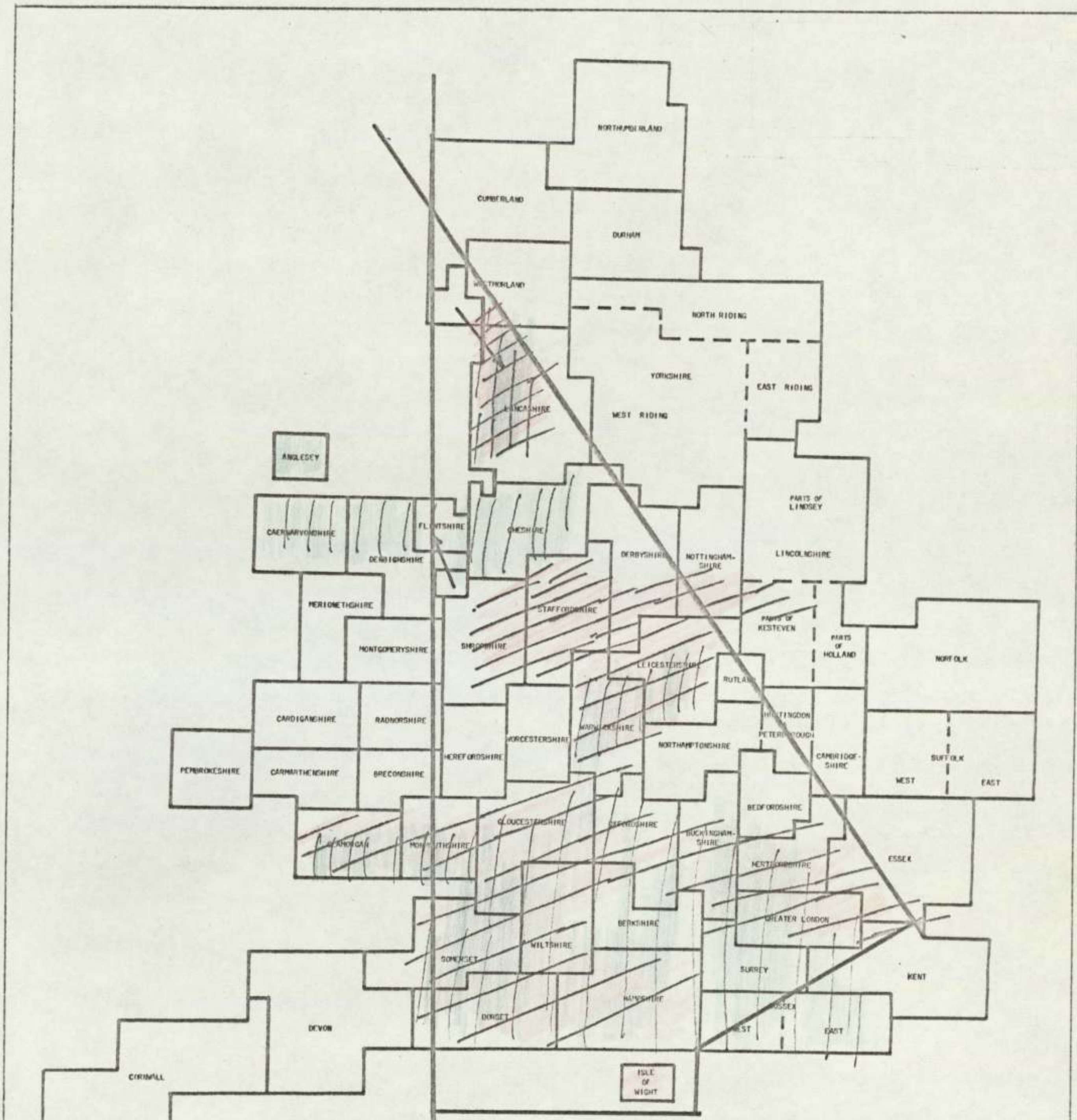
68. As indicated in Terminology, an Area is the sub-regional operating unit of the N.H.B.R.C. In terms of square miles, the size of areas varies from the whole of Northumberland and Durham at one extreme to Birmingham and a small area around it at the other. However, areas are approximately equal to each other in terms of the number of new houses being built within them at any one time. They can, therefore, be used for comparing the incidence of defects to a finer degree than is possible with regions (paragraph 63). Table 12 showed that the North East had only 125 cases out of the 1,028 being studied and the South West region had 206, there being a large difference between these two regions. These two regions are very large geographical areas, one stretching from Berwick-on-Tweed almost to Kings Lynn and the other from Lands End to Banbury. Was the difference in case incidence general throughout the two regions or were more local influences at work? These were the questions that led to the analysis of cases by areas.

69. Table 15 shows the number of cases in each area, the areas being listed in order of the numbers of cases in them. The second column of the Table shows the second order of areas, the basis this time being the number of cases with twelve or more defects, i.e. the cases in which the less serious defect groups tend to predominate. The area numbers refer to Figure 1. Shaded in on Figure13are the areas with the most cases, the red shading for all cases and the green for cases with twelve or more defects. The areas shaded are those coming above the one third line in the Table. The shading shows a high concentration of cases with twelve or more defects, in central Southern England and the bulk of all cases being on a corridor stretching from Hampshire in the South to Lancashire in the North West passing through the West Midlands.

ALL CASES | CASES WITH OVER 12 DEFECTS

Area No.	Area	No. of cases	Area No.	Area	No. of cases
12	Stafford and Salop	58	20	Bucks, S. Herts, S. Beds.	9
13	South Wales	54	29	North & West London	8
21	South Essex	44	2	Mid-Lancashire	7
27	Hampshire	44	1	Cumberland, Westmorland & North Lancs.	6
30	South & East London	44	5	Cheshire	5
2	Mid-Lancashire	42	13	South Wales	5
15	Leicester & Warwick	40	27	Hampshire	5
1	Cumberland, Westmorland and North Lancs.	39	24	Wilts and Dorset	5
29	North & West London	39	25	Surrey & West Sussex	5
22	Gloucester and Oxford	37	6	North Wales	4
23	Somerset and Bristol	37	15	Leicester and Warwick	4
16	Birmingham	36	22	Gloucester and Oxford	4
11	S. Derby, S. Notts, S. Lincs.	35	23	Somerset and Bristol	4
20	Bucks, S. Herts. and S. Beds.	35	32	West Kent and East Sussex	4
24	Wilts and Dorset	35	28	Berkshire.	4
17	Northants and N. Beds.	30	3	South West Lancashire	2
25	Devon	30	4	South East Lancashire	2
26	Cornwall	30	8	North and East Ridings	2
5	Cheshire	30	11	South Derby, S. Notts, S. Lincs.	2
9	West Riding	30	12	Stafford and Salop	2
32	West Kent & East Sussex	36	21	South Essex	2
4	South East Lancashire	25	30	South & East London	2
25	Surrey & West Sussex	25	33	East Kent	2
28	Berkshire	23	10	N. Derby, N. Notts. N. Lincs.	1
8	North and East Ridings	21	14	Worcester and Hereford	1
33	East Kent	21	17	Northants and N. Beds.	1
3	South West Lancashire	20	18	Norfolk & Cambridge	1
14	Worcester & Hereford	20	25	Devon	1
18	Norfolk & Cambridge	20	7	Northumberland & Durham	-
10	North Derby, N. Notts, N. Lincs.	17	9	West Riding	-
19	Suffolk & North Essex	16	16	Birmingham	-
6	North Wales	13	19	Suffolk and North Essex	-
7	Northumberland and Durham	12	26	Cornwall	-
		1028			100

TABLE 15. DISTRIBUTION OF CASES BY AREAS



KEY: (diagonal hatching) All cases; (vertical hatching) Cases with over 12 defects

FIGURE 13. DISTRIBUTION OF CASES BY AREAS.

DEFECT INCIDENCE BY BUILDERS

70. In the description of methodology in paragraph 50, it was stated that three straightforward facts could be found out about a builder, namely, whether or not he traded as a limited company, the number of new houses built each year and the date upon which he became a registered house-builder. This information could answer three questions. Are limited companies better or worse as far as defects are concerned than unlimited firms? Are larger builders better or worse than small having regard to the numbers of houses built and does a builder meet his liability to remedy defects better after he has been registered some years than at first?

LIMITED COMPANIES

71. Table 16 shows that 83% of the builders whose houses were under investigation in this sample were limited companies. The control showed that only 63% of all house-builders are limited companies. This suggests a correlation between limited company status and incidence of defects.

Builders	% who are limited companies	% who are not limited companies
Builders with defect cases in this study	83	17
Control sample of 1,500 of all builders*	63	37

TABLE 16. PROPORTIONS OF BUILDERS WHO ARE LIMITED COMPANIES

BUILDER SIZE

72. Table 17 and Figure 14 shows that builders building over 500 houses each per year build 16% of all the houses but have only 5% of the defect cases. Builders building under 30 houses each per year build 34% of all the houses but have 65% of the defect cases. A further correlation between complaints and small builders is, therefore suggested. To keep the picture in perspective, Table 18 and Figure 15 show that only 5% of all small builders have cases in the 1,028 under study, whereas 86% of the largest builders do. This is common sense because the chances of a purchaser-motivated complaint are proportional at least in part to the numbers of houses built and a large builder will experience a greater number of difficult purchasers than a small one.

*Source: The National Register of House-Builders

TIME REGISTERED

73. Table 19 shows that builders who have been registered longest appear to have the greatest chance of having defect cases against them. In fact, this is most likely to be because the longest registered builders are the largest.

Builder size group (Number of houses built in 1969)	% of all houses built by size group*	% of defect cases against size group
Over 500	16.0	5.0
100-500	27.0	15.0
50-100	13.0	9.0
30-50	10.0	5.0
Under 30	34.0	65.0
Total	100.0	100.0

TABLE 17. DISTRIBUTION OF CASES BY BUILDER SIZE GROUPS

Builder size group	% of builders in size group having defect cases against them
Over 500	86
100-500	38
50-100	21
30-50	12
Under 30	5

TABLE 18. PROPORTION OF BUILDERS IN SIZE GROUP HAVING CASES AGAINST THEM

*Source: NHBRC confidential data.

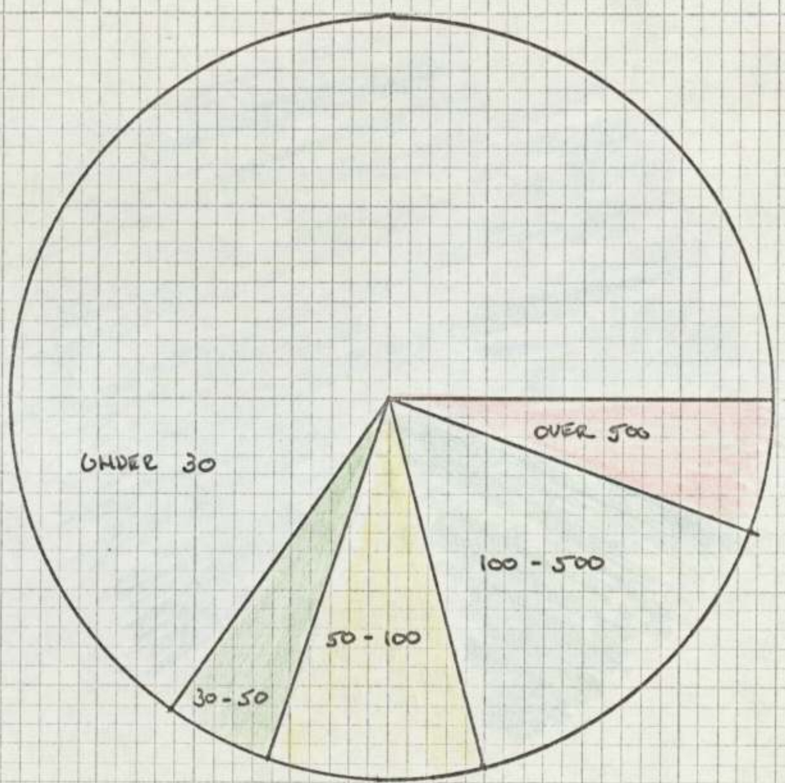


FIGURE 14. PROPORTIONS OF CASES BY BUILDER SIZE GROUPS.

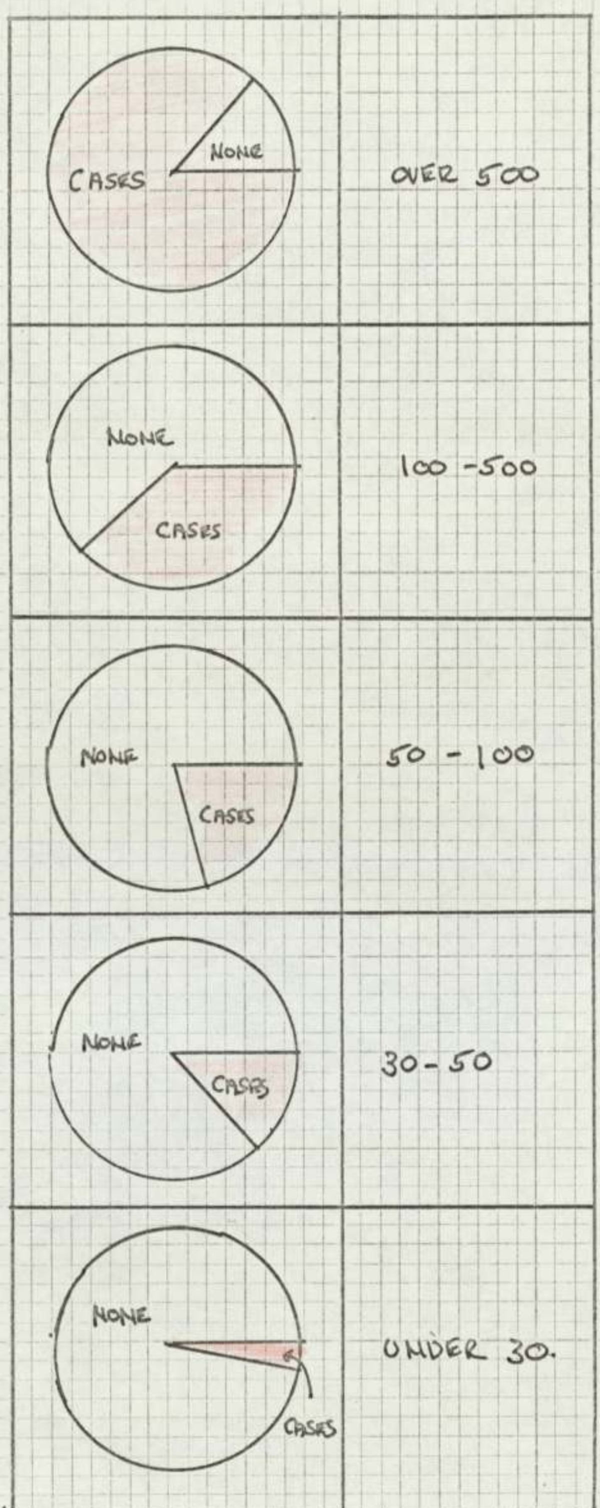


FIGURE 15. PROPORTIONS OF BUILDERS HAVING CASES BY SIZE GROUPS.

When registered	No. of firms still registered at 31.12.69	No. of firms having defect cases against them	% of firms on register having defect cases against them
May 1937	94	7	7.5
May 1937-February 1952	169	22	13.0
February 1952-June 1961	612	54	9.0
June 1961-July 1964	743	100	14.0
July 1964-April 1966	829	116	14.0
April 1966-July 1966	911	89	10.0
July 1966-December 1966	887	84	10.0
December 1966-May 1967	937	71	8.0
May 1967-September 1967	950	44	5.0
September 1967-February 1968	967	30	3.0
February 1968-July 1968	980	19	2.0
July 1968-September 1968	994	9	1.0
September 1968-December 1968	996	17	2.0
December 1968-January 1969	995	11	1.0

TABLE 19. PROPORTIONS OF BUILDERS HAVING CASES BY TIME REGISTERED

IDENTIFICATION OF IMPORTANT DEFECTS

74. One of the first principles of quality control and defect prevention discussed in paragraph 13 was the need to identify a small number of important defects and eliminate them. This is the way to improve quality and prevent complaint. A subjectively compiled list of important defects was given in paragraph 28 . What does this research tell us about the important defects? Which of the 375 defect classes listed in Appendix B are the important ones? Is the list in paragraph 28 realistic or is it misconceived?

CRITERIA OF IMPORTANCE

75. It is first necessary to define importance. The first constituent of importance is frequency of occurrence. The elimination of the defects which occur, or which are complained about, most often will affect the most people for the good. The second constituent of importance is the amount of the industry's resources wasted in remedying the defect. The index of the resource use is cost. Therefore, it would be wise to look for the most costly defects. But the most costly defects may be isolated fortuitous occurrences so it appears better to look for the most frequent of the most costly defects. It will be shown subsequently that these two criteria of frequency and frequency/cost produce two completely different lists of important defects. The frequency list tends to consist of items which annoy purchasers but which are not in themselves serious from the point of view of the performance of the essential structural weatherproofing and operational efficiency functions of the building. The cost/frequency list produces major building items. To bridge the gulf between these two criteria, it is necessary to distinguish first between serious and non-serious defects, irrespective of cost, and then to select as being important the most frequent of those classified as serious.

FREQUENCY

76. Table 13 shows that when all defect cases are considered, the largest defect group is initial building movement in excess of normal tolerances. As a group of defects, this is, therefore, important under the heading of frequency.

77. The twenty most frequently occurring of the 375 different defect classes are listed in Table 20. These top twenty defects account for 18.3% of all defects and they occur in 6.7% of cases for the most frequent, down to 4.2% for the least frequent.

COST AND FREQUENCY

78. Table 5 showed that in the 1,028 cases being analysed, there were 104 defects whose remedial cost was estimated at being over £100.00. Just under half these high cost defects are drawn from only eight different defect classes. These defects are, therefore, the most important in terms of frequency/cost. Information on them is given in Table 21.

Defect class	% of cases in which defect was reported.	% of all defects accounted for by this class
Rough internal paintwork	6.7	1.2
Incomplete external paintwork	6.5	1.2
Missing mastic to windows	6.3	1.2
Incomplete internal paintwork	5.6	1.0
Bath/tiling shrinkage gap	5.3	1.0
Drive ponding/falls/levels	5.3	0.9
Ill fitting internal doors	5.1	0.9
Ease external door	4.9	0.9
Cracks in wall plaster	4.8	0.9
Incomplete plaster making good	4.8	0.9
Flaking plaster	4.6	0.9
Breakdown of external paintwork	4.6	0.9
Faulty pumps, switches, valves and thermostats	4.5	0.8
Loose wall tiles	4.5	0.8
Loose or cracked floor tiles	4.5	0.8
Loose glass or putties	4.3	0.8
Leaks in pipes, radiators or boilers	4.3	0.8
Roof leaks around chimneys	4.2	0.8
Movement of window sashes	4.2	0.8
Rough plaster/uneven wall areas	4.2	0.8
TOTAL	-	18.3

TABLE 20. FREQUENT DEFECTS.

DEFECTS OF REMEDIAL COST OF OVER £100	
Defect class	Number of occurrences
Floor fill settlement	13
Joist/partition shrinkage	9
Subsidence	6
Cavity bridged	5
Retaining wall not provided	5
Missing damp proof membrane	4
Water on oversite	4
Faulty flue linings	4
TOTAL	50

TABLE 21. FREQUENT COSTLY DEFECTS

SERIOUSNESS AND FREQUENCY

79. It was explained under methodology in paragraph 51 that defect classes were grouped into four seriousness categories. Three or four categories are normally recommended in quality control work. Group I was taken as 'Very serious structural'. Defects in this group were those that were positive structural failures or high risk structural failure and decay of structural timbers and missing damp-proof courses and membranes. Group II was taken as 'Very serious, non-structural'. This consisted of items such as damp penetration through walls and roofs, smoke nuisances, plaster and mortar breakdowns, wet rot, inefficient plumbing and heating fittings, leaks in pipework, settlement of drives and faulty drains. Group III was taken as 'Less serious' and includes all the shrinkage and warpage defects except joist shrinkage which was included in Group I, missing tank covers, walk boards in the roof, incomplete pointing, loose basins, loose or flaking plaster, loose wall tiles, paint breakdown and failure to clear rubbish from site. Group III, therefore, consists of positive identifiable items but they do not really affect the 'liveability' of the house'. Group IV are the non-dynamic defects which offend some people. This group is taken as 'non-serious'. It includes all defects related to line and level, minor annoyances such as ticking soil pipes or scratched glass, splashed brickwork floors and drives, and rough but functionally adequate plastering and decoration. The seriousness group allocated to each defect class is given in Appendix B.

80. The allocation of the defects to the various groups is given in Table 22, for, firstly, all defects and, secondly, the defects estimated at over £100.00 remedial cost. The majority of 'all defects' are in Groups II and III but 43.5% of the over £100.00 defects are in Group I. This is consistent with the predominance of high cost defects in the foundation and structural stages already discussed in paragraph 61.

Seriousness Group	% of all defects in this group	% of over £100 defects in this group
I - Very serious, structural	2.3	43.5
II - Very serious, non-structural	30.9	36.2
III - Less serious	37.8	6.5
IV - Non-serious	12.2	6.8
Defects whose class is 'Various' and cannot be allocated.	16.8	7.0
TOTAL	100.00	100.00

TABLE 22. PROPORTION OF DEFECTS BY SERIOUSNESS GROUPS.

DEMERITS

81. In accordance with the systems recommended by Juran[17] and others, demerit ratings were assumed for each of the four seriousness groups. Ratings chosen were: Group I - 100, Group II - 50, Group III - 15 and Group IV - 5. These ratings are arguable because they depend upon a subjective opinion. The object of using the de-ratings is to arrive at the most important defects in terms of frequency/seriousness by using the formula,

Seriousness value of defect = frequency of occurrence x demerit rating.

The effect of taking a low de-merit value for the lowest class is that it will not rise to the top of the seriousness list unless its frequency is exceptionally high. These demerits produce the list of twenty most important defects shown in Table 23. The substitution of other demerits would produce other lists. The only high cost defects also appearing in the seriousness list is joist/partition shrinkage and five of the most frequent defects occur in the frequency/ seriousness list

82. CONSOLIDATED IMPORTANCE LIST

It has been shown that frequency, cost and seriousness are all legitimate definitions of importance but when each is applied as a criterion a different list of important defects emerges. Taking an overall view of the industry and taking all three criteria as of equal importance, the logical conclusion is to construct a consolidated list or matrix based on the three constituent lists. Such a consolidated list is given in Appendix A, Schedule 2.

---

17. J.M. Juran 'Acceptance of Qaulity', Section 8, Quality Control Handbook, McGraw Hill 1962.

Defect class	Frequency of occurrence. (% of all cases)	Demerit	Rating
Joist/partition shrinkage	0.5	100	50
Cavity bridged	0.5	50	25
Damp entry at jambs	0.7	50	35
Roof leak by chimney	0.8	50	40
Broken/loose vertical tiles	0.5	50	25
Leaks at gutter joints	0.7	50	35
Non-alignment/overflow of gutters	0.6	50	30
Loose/missing mastic around windows	1.2	50	60
Provide weather bar to door	0.5	50	25
Damp entry around door	0.5	50	25
Replace warped external door	0.5	50	25
Loose pipes/water hammer	0.5	50	25
Missing wire balloon (Soil)	0.7	50	35
Leak at WC/soil joint	0.6	50	30
General leaks in plumbing pipes	0.5	50	25
Faulty pumps, switches, valves and thermostats	0.8	50	40
Leaks in heating pipes, radiators or boilers	0.8	50	40
Loose or cracked floor tiles	0.8	50	40
Ponding, falls and levels to drives	0.8	50	40
Man-holes, levels, loose or cracked renderings	0.5	50	25

TABLE 23. FREQUENT SERIOUS DEFECTS.

PART IV

DISCUSSION OF RESULTS

THE CAUSES OF DEFECTS

TECHNICAL AND BEHAVIOURAL CAUSES

83. It will be appreciated that for a defect to exist in the data for this thesis, two main conditions must have been met. There must have been a defect in the building in the first place, that is, there must have been a technical cause or origin and, secondly, there must have been motive for complaint, that is, the purchaser must have thought the defect worthy of complaint both to the builder and to the Council and the builder must have failed to either remedy the defect or persuade the purchaser to change his mind. In this section, consideration will be given to the technical aspects first and afterwards to the broader behavioural ones.

CAUSES OF DEFECTIVE BUILDING

EXTENT OF THE BUILDER'S RESPONSIBILITY

84. In speculative house-building, as in all package deal building projects, the builder is absolutely responsible for all aspects of the product. He buys the site with all its geological and climatic attributes, he designs the dwellings with care and with sympathy for the site or otherwise, he engages the site management, he employs the labour directly or through sub-contractors, he determines the cost budgets and the acceptable standards of work. Apart from meeting his statutory obligations and his obligations as a registered house-builder, he is entirely his own master. Because of his autonomy, he is responsible for the success or failure of his buildings. It can be stated bluntly that all the defects are his fault. Of course, he will occasionally make mistakes after carefully thinking about problems and accidents happen which even the wisest man would not have foreseen. Given this basic premise, it is possible to go on to see where and when in the construction process the mistakes are made.

TYPES OF ERROR

85. The most fundamental error a builder can make is one of design. A design error can be major, such as foundations inadequate for the ground condition of the site or a roof which is not triangulated. More common, perhaps, are errors of detailing leading to damp penetration at vulnerable points or to unworkmanlike construction. It was probably this type of error which Feld had in mind when he suggested that many bad details were used uncritically (paragraph 10). Next come errors of construction management, particularly at site level. The error can be failure to provide competent personnel for supervision or execution and failure to monitor performance at all levels. In an industry of high labour mobility between firms and between sites within a firm, it is not easy to decide which workers are competent and conscientious and which need guidance or control. Not every minute operation can be supervised but all errors in execution of work by operatives are, nevertheless, part of the sum of errors made by the builder. Lastly, the builder as buyer and assembler of materials and components, is responsible to the purchaser for faults in them. They may be described as errors of purchase and errors of use. Table 24 shows the main types of error and the proportions of defects due to that particular error. The person considered responsible for each defect type is shown in Appendix B.

DESIGN ERRORS

86. Design errors include subsedence, inadequate retaining walls and site drainage, unsuitable gradients to drives, under-sized structural timbers, chimneys of insufficient height, inadequate joinery detailing to take account of local climate, failure to provide for cover moulds, or similar precautions in positions where shrinkage is inevitable and minor defects in plumbing design.

SITE SUPERVISION ERRORS

87. Site supervision errors are divided into four types. Control of critical operations includes failure to oversee the placing and

consolidation of underfill, the correct position of D.P.C.'s, lintols being placed the right way up and joists being over-notched for services. Mostly, these are things which are visible for a short time after they are completed and they are crucial points for which an agent or foreman should look. He is responsible for dry storage of materials and for condemning unacceptably rough work. These are matters for which he alone has over-riding authority on site. Finally, it was found that 18.7% of defects are generally minor things that could be corrected before hand-over of the property to the purchaser if there was a methodical check in roof spaces for provision of items such as walk boards and tank covers, externally for pointing of putlog holes and around waste pipes, and in each room for damaged doors or splashed floors.

WORKMANSHIP ERRORS

88. The operative has to be held responsible for the minutiae of construction, particularly matters of fixings and jointing whether correct tucking in of a flashing or the inadequate preparation of woodwork to receive paint. These are matters of basic operational skill and perhaps even more of care.

MANUFACTURED GOODS

89. The points here are mixed. Faulty and leaking gutter joints are included and the need to replace warped doors. The reason for this is that many gutter jointing systems and many doors bought for external use are insufficiently robust for use on site unless great care is used. The builder has a choice between using delicate components with care, or using more robust ones requiring less care.

QUANTITATIVE RESPONSIBILITY

90. Table 24 shows the allocation to the four categories for both all defects and the over £100.00 defects. In both cases, site supervision

accounts for 35-37% of the defects. Design is responsible for 33% of the over £100 defects but for only 10.6% of all errors. Workmanship is responsible for 30.6% of all defects and for 17.7% of the over £100 defects. Manufactured goods is a small category in both cases.

CAUSES OF IMPORTANT DEFECTS

91. Important defects according to frequency, cost and seriousness were noted in Schedule 2 of the Appendix. The cause of each particular occurrence of a defect was not extracted from the original data because, in many cases, the cause is not, in fact, stated. A symptom is given by the purchaser and a remedy is recommended. The causes is, in some cases, obvious and, in others, a good guess can be made but often the cause of the defect is not clear. In Schedule 3, the common defects are taken from Schedule 2 and possible symptoms and causes noted for each item. This work is distillation of impressions left from the study of the data and from additional information gained from subsequent discussions amongst N.H.B.R.C. Investigating Officers. The format of Schedule 3 is similar to that used by Bowyer and discussed in paragraph 9.

TABLE 24. MAIN CAUSES OF DEFECTS

	% of all defects		% of defects over £100.00	
Defects primarily attributable to design.				
Selection of site and design of appropriate foundations, groundworks and drains	1.4		19.4	
Design faults in superstructure	1.6		4.9	
General joinery detailing	1.2		-	
Failure to design for shrinkage	5.9		8.7	
Design faults in plumbing and engineering services	0.5	10.6	-	33.0
Defects primarily attributable to site supervision				
Failure in control of critical operations	3.9		27.1	
Shrinkage due to failure to keep materials dry	8.8		4.0	
Failure to condemn rough work	4.4		3.9	
Failure to check the house systematically before handover	18.7	35.8	1.9	36.9
Defects primarily attributable to workmanship.				
Bricklayer	3.5		4.9	
Carpenter and Joiner	9.1		-	
Roof tiler	4.2		1.0	
Plumber and Engineer	3.9		2.9	
Plasterer and Pavior	4.8		5.9	
Painter and decorator	3.8		-	
General	1.3	30.6	3.0	17.7
Defects primarily attributable to material behaviour and manufactured goods				
Bricks, plaster and glass	1.5		1.0	
Timber and manufactured joinery	4.6		-	
Plumbers and engineers goods	3.0	9.1	1.9	2.9
		13.9		9.5
		100.0		100.0

DAMP PENETRATION DEFECTS

92. Damp penetration defects noted in Schedule 3 are only some of the wide range of damp penetration defects which occur, particularly in the Western half of the country. This is an important group of defects, not only numerically but mainly because it represents failure in the most basic building function of all - the exclusion of wind and rain. Historically, buildings were not designed mainly to keep people warm or even to be structurally stable for long periods, but they were designed to exclude the weather. Rain borne by wind is the great enemy of the builder and to exclude it in places of extreme exposure requires great skill in design and execution. Sir John Laing, the head of one of the largest British groups of building companies, has said that Carlisle is the hardest place to build in the whole of England because of the problem of wind and rain. Wimpeys, the largest house-builders in England, made grave mistakes when first going into the far South West because the details they had used for window and reveal construction in central and Southern England were found not to stand up to the rigour of persistent rain. In the field of damp exclusion, expertise is local and vernacular. The B.R.S. Advisory Service paper mentioned in paragraph 4 barely hints at the detail of the problem. The twin root causes of damp penetration defects are lack of pains in construction and failure to follow explicitly the local vernacular details.

GROUND WORK DEFECTS

93. A general comment is needed on the three structural defects upon which detailed comment is made in the Schedule. The data are not sufficiently detailed to give precise case data but it is highly likely that the floor fill settlement defects, the subsidence and the non-provision of retaining walls have a common origin. This is the increasing use of sloping sites, split-level houses and made up ground. Observers of the house-building scene say that in many parts of the country, houses are now being built on land which ten years ago, not to say pre-war, was considered unfit for building. There is no general reason why such sites should not be used. It is possibly better for society that they should be rather than that there should be further inroads into green belts and countryside. Builders must, however, recognise that building on sloping, wooded, wet or made up ground imposes unfamiliar and some times complex problems. If ground strata are investigated and foundations designed accordingly, if adequate site drainage is provided if underfilling is closely supervised or obviated by design, all will be well. These problems must be faced and, what is harder, the cost implications of them accepted. This is especially hard where poor sites are to be used for low cost housing and the builder is under pressure to omit all but the essentials of the construction. The quality of land will presumably decline still more in years to come and this will continue to be a cause of major defects unless hard design and cost discipline are accepted.

MOVEMENT DEFECTS

94. Initial building movement in excess of normal tolerances accounts for 21.5% of all defects. (Table 13). It is numerically the most significant defect group in all regions (Figure 11). Some of the more important defects are discussed in detail in Schedule 3. The most frequent problems relate to drying or hygrothermal movement, but structural movement also accounts for some defects. These two types of movement were identified in the Concrete Society work discussed in paragraphs 6 to 8. Movement is more prevalent in dry counties than in wet as discussed in paragraph 67.

PROXIMATE CAUSES

95. The proximate causes of movement are the natural behaviour of materials, excess shrinkage due to excess moisture takeup due, in turn, to lack of care in storage, particularly of timber. Twist and bow are due to the moisture sensitivity of slender section joinery. Dryer atmospheres lead to greater moisture movement than moist atmospheres and this is a contributory factor, if not the main reason why movement defects are more prevalent in the dry counties of Essex, London and Northants and Surrey than in the damp counties of Cheshire, Cornwall, Devon, Glamorgan, and Lancashire.

TECHNOLOGICAL CHANGES

96. Moisture movement is a key problem today. There are no figures to substantiate that is more significant today than, say, twenty or thirty years ago but this is the view taken by many building people. Why?

The hypothesis is that a series of unrelated changes in building practice have combined to destroy what may be called the moisture stability balance of the building. These changes include the introduction of central heating leading to faster drying, to the use of light, slender section joinery more prone to twist and warping, the use of aerated concrete blocks which have higher hygrothermal properties than brick. The departure for cost reasons from multi-piece self masking joinery of the type advocated in the Concrete Society paper (paragraph 8), the change from soft to hard wall plasters may also have introduced another crack-prone material. The argument is that on the one hand central heating has made the atmospheric environment more conducive to drying and house movement and that constructional changes have made the risks of movement and cracking greater.

ATTITUDES TO MOVEMENT

97. The technological fact of considerably greater numbers of movement defects gives rise to a choice of responses. The first possible response is to say that movement is inevitable and to seek to quantify the extent of inevitable movement and say that any movement within these tolerances is not a defect, even though it may be highly distasteful to purchasers. This is the philosophy which underlies the N.H.B.R.C.'s tolerance rules quoted in paragraph 32 and some of the Greater Milwalkee carpentry items listed in Schedule 1 of the Appendix. The alternative response, and the better one, is to say that movement is an inevitable fact, the effects of which are often distasteful to the purchaser and it is the job of the builder as the

professional to design to take account of it. This is why failure to design for shrinkage is included as one of the groups of defects attributable to design inadequacy, (Table 24). These two responses will be considered again under the heading of 'Prevention of Defects'

CAUSES OF COMPLAINT

COMPLAINING AND NON-COMPLAINING PURCHASERS

98. The probability of a defect occurring and falling within the data for this thesis was discussed in paragraph 55 and the following formula suggested:

$$P = P_d \times P_o \times P_a \times P_r \times P_n \times P_c \times P_j$$

Are all the defects which occur observed, appreciated and reported by purchasers? There is no known answer to this question but commonsense suggests that the answer is 'no'. The situation shown in Figure 4 and discussed in paragraph 55 also suggests 'no'. The evidence is that when all causes are considered, the less important defects are relatively more numerous. When only one defect occurs in a case, the items are most serious. Does this mean that in the one defect houses the less important items of movement, fixings and most strikingly (Figure 10) incomplete work, do not exist? Would a builder who fails to remedy a structural defect or a damp penetration defect nevertheless remedy shrinkage or double-check his houses so that nothing is omitted or left incomplete? The answer must be 'no' to both these questions. The difference in the nature of cases must lie in the $P_o \times P_a \times P_r$ part of the probability formula, i.e. with the purchaser.

SOCIAL CLASS AND OTHER CHARACTERISTICS OF PURCHASERS

99. A comparison was made between 100 cases with twelve or more defects, (the top 100 cases) and 100 of the cases with only one defect to isolate variables. On the basis of correspondence, estimates were made of the social classes to which purchasers belonged. Table 25 shows that the

purchasers whose social class is AB buy 19% of new houses but account for 51% of the cases with twelve or more defects. Therefore, AB class purchasers tend to complain more frequently of high numbers of defects than purchasers whose social class is below AB. Table 26 shows that 22% of the purchasers in the cases with more than twelve defects employed surveyors to prepare their schedules of defects as against only 5% in the single defect cases. This means that surveyors help to find defects which is not unreasonable, as they are professionals and can appreciate defects when they see them, whereas laymen may not do so.

Purchasers	% of purchasers who are Social Class AB
All purchasers of new houses	19*
Purchasers complaining of only one defect	25
Purchasers complaining of more than twelve defects	51

TABLE 25. SOCIAL CLASSES OF NEW HOUSE PURCHASERS

Characteristic	% of cases in which characteristic was apparent	
	1-defect cases	over 12 defect cases
Purchaser employed a surveyor	5	22
Purchaser complained of delay	43	67
Builder had financial problems	10	20

TABLE 26. CHARACTERISTICS OF COMPLAINING PURCHASERS

* Source: 'New Housing in South East England' and 'New Housing in the Midlands'. The Housing Research Foundation 1970 and 1971 respectively.

REASONS FOR HIGH COMPLAINT BY AB PURCHASERS

100. There are no facts available on why such a high proportion of AB purchasers complain of many defects but some hypotheses can be put forward. The AB purchaser is a business or professional man. He is used to ascertaining his rights, conducting correspondence, employing experts, standing out for what he believes to be his rights and finding satisfaction in doing so.

REASONS FOR LESS COMPLAINT BY CDE PURCHASERS

101. The counterpart of the argument put forward in the last paragraph would be that the CDE purchaser does not complain because he is less able to do so. This is unlikely to be so, however, as even if a man is bad at formal communication, he will communicate somehow if he feels sufficiently strongly about a matter. The reason for non-complaint is more likely to be that the CDE purchaser tends to be more easily satisfied with his house. He may have come from a poor standard, older house and be delighted with the amenities of his new house, even though its standards may not be unduly admired by him. He may be more ready than his AB counterpart to carry out remedial works himself.

OTHER CAUSES OF MULTIPLE DEFECT CASES

102. The 100 or so cases with more than twelve defects were divided in origin about equally between AB class purchasers and purchasers of a lower social class. Social class, therefore, is not the only factor influencing the incidence of cases with more than twelve defects.

103. A very small number of the cases studied indicated that the purchaser was a perfectionist so far as building was concerned. He wanted a very high Standard, particularly in the controversial fields of building accuracy and general quality of workmanship. These people were often

either surveyors or engineers, or retired service officers. The surveyors expected very high price building contracting standards, the engineers expected engineering precision in building and the service officers expected the builder to observe the same standards and respond as speedily to their whims as a military works department.

104. Table 26 shows that complaints about builders' delay and evidence of financial problems are more prominent amongst the multi-defect cases. The motives underlying these situations are that the more the builder delays, the more minor defects the purchaser finds almost out of spite. When he knows the builder is in financial difficulty, a purchaser tends to collect together all possible items for remedy before it is too late and the builder becomes bankrupt.

105. NON-REMEDYING OF DEFECTS

The next factor in the probability equation is P_n, the probability of the builder not remedying defects. The study of a sub-sample of 50 cases showed that in 55% of them there was written evidence of the purchaser's dissatisfaction with the builder's service, whereas in only 33% of cases was there any evidence of disagreement on the technical extent of remedial work or whether a defect, in fact, existed. See Table 27. The essence of the dispute is the failure of the builder to say what remedial work he will do in respect of agreed defects, or to do work which he has specifically said he will do. The Housing Research Foundation work described in paragraph showed that 50-53% of purchasers of new houses were dissatisfied with the after-sales service given to them by their builder, so it is a very widespread problem. Why are builders slow in after-sales service? Why do they not remedy defects?

Factor	% of cases in which the factor was apparent
Dispute on whether an item was or was not a defect or the extent to which it should be remedied	33
Failure by the builder to say what remedial work he would do in respect of agreed defects or when he would carry out agreed remedial work	55

TABLE 27. FACTORS CAUSING COMPLAINT

SHORT AND LONG TERM BUSINESS POLICIES

106. The prime object of businesses is to make profits. It is hyprocrisy to suggest anything else as a prime object. A business can be established on a short term basis or a long term. With the short term business, the entrepeneur will look for minimum investment, minimum expenditure and maximum return. Expenditure is kept to absolute minimum. In a long-term business, the object is to make profits today but also to go on making them tomorrow. Today's actions must not reduce tomorrow's profits. It is better to spend a little more today if it is going to increase tomorrow's goodwill and hence tomorrow's business. The long-term business wants it clientsto return a second time and to recommend it to their friends. The short-term business wants to retain the maximum amount of the client's money today and there is no tomorrow. In industries like construction where a high level of capital investment is necessary, a large business almost necessarily means a long-term one. A short-term large business is impossible as a policy. With small businesses, the choice is open. A small business can plan for a long life, building up a clientele and a reputation, or it can plan for short-term maximum gain.

107. REMEDYING DEFECTS AS AN EXPRESSION OF POLICY

In house-building, as in any business, a long term policy means satisfying the customer at almost all costs. One dissatisfied customer can do great harm to goodwill and to tomorrow's business. This means remedying what the customer regards as defects in his house, even though he may be very fussy and very hard to please. A short term business with sound ethical principles can afford not to pamper to the fussy customer. It can remedy what it regards as legitimate defects and stop there even though the customer may still be dissatisfied and even though he may campaign to the detriment of the firm's name. If a short-term business is based on low ethical principles, it can afford not to remedy all but the most serious of defects and leave behind it an even greater trail of dissatisfaction. On the basis of these arguments, it is wholly reasonable that in half the dispute cases summarised in Table 27 the builder should be avoiding spending money where the defects are not critical and are even such that although technically breaches of the Agreement, they would be acceptable to many other purchasers.

FINANCE FOR REMEDYING DEFECTS

108. It needs to be said that if a builder has no money even though he may wish to remedy defects, he cannot and the purchaser will have to suffer or, in the event of liquidation, claim on the insurance provisions of the Agreement. Insolvency is a legitimate reason for not remedying defects.

109. Two false arguments are often advanced concerning finance for remedial works. A builder says he is prepared to do work to satisfy one, albeit rather demanding purchaser, but he cannot afford to do it for all the neighbouring purchasers who are in the same position. This argument pre-supposes that other purchasers will follow suit after an extreme individual and will be prepared to have remedial work done in their houses. The truth of this is doubted. Some people are not fussy in their attitudes to building and do not like builders in the house. Moreover, fussy individuals trying to foist their ideas on others are not always popular in the neighbourhood. The other false argument is that the defect is due to a sub-contractor who has been fully paid off. This is no fault of the purchaser and it is the duty of the builder to keep an adequate grip of sub-contractors during both construction and the liability periods.

LIMITED COMPANIES

110. The arguments put forward in paragraphs 106 & 107 to explain reasons for delay by builders are impressionistic but facts can be adduced in

support of the. Table 16 suggested that disputes were more likely to involve builders who were limited companies than those who were not. There are two possible reasons for this. Table 18 shows that most large firms were involved in dispute whereas few small ones are. Larger firms are virtually always limited liability companies, so it follows that they will tend to increase the proportion of limited companies in the disputes field. This is a small factor because the number of large firms is small. Secondly, the limited company itself is a defensive mechanism. It protects the shareholders and limits their risk. They are not putting all they have got into the business. A business with a short term maximum profit today philosophy is unlikely to trade other than as a limited company in order to protect itself from the possibility of maximum loss today.

LARGE AND SMALL BUILDERS

111. Table 17 showed that large builders (over 500 houses per year) build 16% of the houses but have only 5% of the dispute cases whereas small builders (under 30 houses per year) build 34% of the houses and have 65% of the dispute cases. It has been argued that a large business is almost by definition a long term business and in order to be long term a business has to satisfy its clients at almost all costs. A large firm, therefore, has a motive for speedy after-sales service and it also has sufficient business to have a service department and because of the value of business it can place, choice and control of sub-contractors. A small firm is at a disadvantage so far as these means of good after-sales service are concerned and, if it has a short-term policy, it does not have the motive. Large firms may also have internal quality control systems. One large firm has a very simple scheme whereby its sales department takes over completed houses from the construction department, but only when they are satisfied that a satisfactory standard has been achieved. A house cannot be sold until

it has formally been taken over by the sales department. These may be some of the reasons why large firms have fewer defects. It would be erroneous to assume that large firms build better than small firms.

SMALL BUILDERS AND DISPUTES

112. An examination was made of the general files of 80 of the small builders with cases under investigation. Data about these firms were compared with a control of equal size drawn at ramdom from all builders. Comparative results shown in Table 28. The picture that emerges accords with that of a short-term ad hoc business with some evidence of financial difficulty, membership of a group of companies and with some instability. This is the kind of firm that is set up for tax avoidance or risk limiting purposes. The fact that it is an entrepreneurial type of firm is indicated by the presence of the estate agent, the solicitor or accountant on the Board. It tends not to be a genuine small craftsman builder.

Characteristic	% of builders in which characteristic was apparent	
	Small builders with defects	All Builders
Member company of a group	31	19
Financial difficulty	24	12
Recent board changes	19	10
Estate agent, solicitor or accountant on board	15	6

TABLE 28. CHARACTERISTIC OF SMALL BUILDERS INVOLVED IN DISPUTES

JUSTIFICATION OF COMPLAINTS

113. The final element in the probability of analysis of complaints and defect incidence is the justification or otherwise of the item by the N.H.B.R.C. Investigating Officer, i.e. P_j in the probability formula.

114. NON-CONTROVERSIAL ITEMS

A small investigation was carried out into some fifty cases to find out what types of alleged defects tended not to be justified by N.H.B.R.C. Investigating Officers. These are items comprising the green colour block of Figure 4. Some of the items were rejected for legal reasons, such as not being reported to the builder as soon as possible or within the guarantee period. Other items were due to genuine ignorance on the purchaser's part about building. For example, purchasers were often worried about mild condensation and did not appreciate that steady ventilation and warmth would quickly reduce it in conventionally constructed dwellings. There were requests for the provision of items which although commonly provided by builders are not mandatory under the Agreement and, therefore, cannot be insisted upon and accepted as defects under the terms of the Agreement. A jacket to the hot water cylinder is a typical example of something that is very common but not mandatory. All these items are clear cut and lend themselves to a 'go/no go' decision.

Liability of the builder for damp penetration defects, loose items and incomplete work, structural inadequacy was easily established and universal.

CONTROVERSIAL ITEMS

115. The investigation into unjustified items revealed that three of the defect groups identified in this thesis were highly controversial. These were; Initial Building Movement, Building Inaccuracies and

General Unacceptable Workmanship. These are the three groups put under the generic heading of 'Matters of Tolerance' in Table 13. It was in these three fields that purchasers and builders could not readily agree. There was also evidence of a high degree of subjective judgment on the part of the Investigating Officers, some of whom tended to allow certain types of defects and some of whom did not.

SPECIFICATIONS AND TOLERANCES

116. The cause of the controversy is that the Agreement and the Specification enjoined by it are not specific and do not give tolerances. The first principle of quality control, that nothing is perfect and everything is subject to tolerance, as noted in paragraph 13 is not made definitive in building specifications. The language of specifications is the language of perfection - smooth, level, plumb, of good workmanship, free from blemish. This type of language is of no consequence where both parties to a contract agree on what is an acceptable standard of imperfection but when there is a difference of opinion, the argument can be very vexed. The purchaser argues that the builder is legally committed to perfection and the builder argues that the normal practices of the industry for the price and for the area is all that should reasonably be expected. The Agreement and Specification cite no tolerances of the type suggested in the B.S.I. Draft for Development, (paragraphs 31 and 32) or similar to items C1, C3, C4 and C5 of the Greater Milwaukee work, shown in Schedule 1 of the Appendix.

CAUSES OF REGIONAL VARIATION

REVIEW OF INCIDENCE OF DEFECTS GEOGRAPHICALLY

117. Paragraph 24 and 63 indicate that defects increase in frequency from North to South and from East to West. The East-West trend is due in part to the greater proportions of damp penetration defects resulting from more rigorous climatic conditions. Early indications of this

trend were discussed in paragraph 24. The increase in defects from North to South is not accounted for by climatic reasons. Indeed, it is the reverse of what would happen if climate were the only factor. It is also the reverse of what would be expected to follow in the work discussed in paragraph 25 in which it was established that general building standards were lowest in the North West and highest in the South East. The map in Figure 13 shows that defects mostly occur in North West, Central and Southern England. They tend not to occur in the extreme North, the North East, East Anglia, the far South East and the far South West.

THE PROBLEMS

118. The above summary of regional incidence raises two problems. The first is to find out why defects increase from North to South, whereas what is known about climatic and building standards suggest that the reverse should be the case. The second problem is to find out why the bulk of Northern and Eastern England is free of defects.

THE NORTH WEST

119. The most marked differences between the North West Region with 174 cases and 997 defects and the North East Region with 125 cases and 528 defects. This problem was discussed with builders deeply involved with work on both sides of the Pennines and with N.H.B.R.C. Managers with similar experience and with employers organisations. The essence of their views was that the building labour history and general economic history since the Industrial Revolution has been fundamentally different in the two regions. In the North West, there was considerable building of factories and dwellings up to about 1870. When the factories had been built, labour moved from the sites to work in the factories and has, of course, never returned. Labour for building work in more recent years has been imported from Northern Ireland where building

standards are very low indeed. Now that the building stock, particularly of dwellings, is at a very low ebb, large scale renewal is being carried out but the labour force in the region is inadequate in numbers and skill. The population is essentially a working class one and it is low cost homes that are required to replace the back-to-backs of nineteenth century Lancashire. Because labour is short, costs are high. Liverpool is the highest paid building area in the country outside London and it also has a long history of industrial unrest and low productivity in building. Because labour is unskilled, standards tend to be low. Because the market is working class and not in the Midlands boom area, prices have to be kept down. These factors, together with the demanding climate, combine to produce inadequate building.

THE NORTH EAST

120. The North East of England has had a long history of depression, especially in shipbuilding. There has been widespread unemployment of even skilled labour. There has been little opportunity for skilled labour to move out of building into industries where comforts are greater. Added to this, the skills required for shipbuilding are somewhat similar to those required in building. In some fields, such as joinery, shipbuilding is a more exacting field than general building and has developed higher levels of skill in the artisan population. The general picture is that building and shipbuilding have built up a pool of very skilled labour which has not been lost to other industries. The unemployment has made men value their jobs. In such circumstances, good building must result. A note of warning is, however, needed. The North East has lately become a development area and manufacturing industry has grown up in the Tyneside and Teesside areas. There is evidence of loss of skilled building labour to these industries. One manufacturing firm on Teesside recruited 80 skilled bricklayers and

80 skilled joiners for semi-skilled factory work in three to four years. If this is a major trend, within a generation the traditional skills of the region will be lost, especially if shipbuilding goes into decline.

AGRICULTURAL AND OUTLYING AREAS

121. It can be seen from Figure 13 that the areas of low defect incidence correspond with the agricultural areas of the East Midlands, Lincoln and East Anglia and the horticultural area of Kent. Here there is very little industrial competition for labour. Experience of building in Norfolk, Suffolk and rural Essex is that the labour force is very intelligent, very skilled and very stable. In these areas, there are men working as building tradesmen whose technical qualifications, experience and general ability would take them far if they were to move to areas of high labour demand. They prefer, admirably, to stay in the country areas where they were brought up and to continue to work for the firms who trained them. The same is probably true of Northumberland, Cumberland, Westmorland, Devon and Cornwall. These are rural communities. Work is at a premium and building gets good people.

THE MARKET IN THE SOUTH

122. It has already been shown in paragraph 99 and 100 that purchasers of high social class tend to complain more extensively than those of low social class. The Housing Research Foundation studies (paragraph 17) showed that there was a higher proportion of AB purchasers in the South East than in the West Midlands. This is shown in Table 29 below. The same report also states that 50% of new house buyers in the South East are buying their second or subsequent house against only 33⅓% in the West Midlands. This means that the Southern buyer is an experienced buyer whereas his Midlands counterpart is not. Because he is buying for the second time, he may be moving up the social ladder, expecting higher standards, exercising his authority against the builder. If the

property is on the South Coast, he may well be retired and have the time to pursue arguments with the builder which in his working life he would have abandoned. There are cases where the argument with the builder is clearly one of the hobbies of the purchaser.

Social Class	% of new house purchasers in social class	
	West Midlands	South East
AB	16)	31)
	) 47	) 72
C1	31)	41)
C2	44	24
DE	9	3
TOTAL	100	100

TABLE 29. REGIONAL VARIATION IN SOCIAL CLASSES

123. Cases with more than twelve defects are more common in the South than in the Midlands as shown by the figures in Table 30. The high incidence of these cases in the South added to the number of defects and the increased proportions of those of a minor nature as indicated in Figure 11 where incomplete work and damaged items are proportionately high. The high proportion of cases with twelve or more defects in the North West is probably attributable to bad building as much as to sophisticated purchasers.

Region	No. of cases with more than 12 defects.
North West	21
North East	9
East	12
West	13
South West	20
South East	21
TOTAL	86

TABLE 30. CASES WITH MORE THAN 12 DEFECTS BY REGIONS

124. There is no objective evidence to show that complaints rise with the price of houses but this is the consistent subjective view of many people. Their argument is that the purchaser has paid what he considers to be a very high price for his house, he is entitled to attention and courtesy from the builder and he is going to get it, come what may. Rise in prices from North to South is consistent with rising complaint, but whether there is a common cause, it is impossible to tell.

Table 31 shows the house prices of one national builder which were quoted in the Sidwell report[18].

Part of Country	Price of standard 3-bedroomed house
	£
Extreme North	4,219
Lancashire and Cheshire	4,335
Yorkshire	4,086
East Midlands	4,184
West Midlands	4,360
East Anglia	4,835
South West	4,563
East and South East	5,718

TABLE 31. GEOGRAPHICAL VARIATION IN HOUSE PRICES

18. Norman Sidwell. 'The Cost of Private House Building in Scotland' H.M.S.O., Edinburgh 1970.

THE BUILDERS IN THE SOUTH

125. Large builders have few defects and small builders most defects. This was shown in paragraph 72 and Table 17. The South has more defects than the Midlands and the North. Therefore, does the South have a higher proportion of its houses built by small builders? To test this hypothesis a study was made of houses registered for inspection with N.H.B.R.C. by the largest builders, i.e. those building 500 or more houses a year, to see how they were distributed over the regions. The results given in Table 32 are not conclusive. Overall more houses are built by large builders in the North and the Midlands than in the South. The North West and North East are equal but, as already shown these two Northern regions differ fundamentally in defect incidences. The East and South East are equal so far as numbers of houses built by large builders is concerned but unequal in defect incidence. One could, however, deduce a causal relationship between high number of defects in the South East and low proportion of houses built by the largest firms.

Region	No. of houses registered by the largest builders (over 500 houses per year) in the first three months of 1969.
North West	765
North East	813
West	1,151
East	561
South West	531
South East	628

TABLE 32. REGISTRATIONS OF HOUSES BY LARGE BUILDERS BY REGIONS.

126. A reason for the incidence of minor defects which is commonly advanced is the lack of control that builders have over sub-contractors. During construction they tend to carry out work intermittently and at great speed. Payment is required immediately and it is difficult, if not impossible, to bring them back to make good after other trades and to remedy defects after occupation of the house. Does the incidence of sub-contracting correlate with the high incidence of defects? This was another hypothesis. The only regional statistics available on the use by builders of sub-contractors is the information on labour only sub-contracting in the Phelps Brown report[19]. This information, summarised in Table 33 shows that labour only sub-contracting is most common in the South and least common in the North. There is, therefore, reason for supposing a link between high incidence of sub-contracting in the South and high incidence of defects. The point is not, however, conclusively proven because the sophisticated purchasers of the South East might find equal fault with the work of directly employed labour.

Part of Country	% of firms surveyed by Phelps Brown who had used labour only sub-contracting at some time.
Extreme North	28%
Midlands, including Lancs and Yorks	38%
Southern	63%

TABLE 33. USE OF LABOUR ONLY SUB-CONTRACTING.

19. '<u>Report of Committee of Enquiry under Professor E.H. Phelps Brown</u>' H.M.S.O. 1968.

CONCLUSIONS

PROBABILITY FORMULA

127. The formula for any defect existing and falling within the data for this thesis is:

$$P = P_d \times P_o \times P_a \times P_r \times P_n \times P_c \times P_j$$

CAUSAL FACTORS

128. Each of the causal factors discussed in this Part of the thesis affect the probability of one or more of the terms of the probability formula. Situations leading to high or low probability are summarised in Table 34 . Not all the factors shown in Table 34 affect all defects. For instance, the exposure or otherwise of the site will not affect whether work inside the house is complete or not. The Table merely brings together all the factors that have been identified as possibly applying in any particular situation.

129. PREDICTION OF DEFECTS AND COMPLAINTS

It would theoretically be possible to give a weighting to each of the causal factors in Table 34. That weighting x the probability rating in any particular case would give a derived value. The combination of such derived values could be given a probability prediction. It could possibly be ascertained by experiment what probability prediction would, in fact, lead to a complaint about a defect. It is considered, however, that the greatest variables are the behaviour of the two parties to a dispute and their attitudes to each other. These factors overshadow all the more subtle ones about climate, the quality of labour, the design, that such predictions would not be feasible. One can only emphasise the high probability factors and aim to minimise their effect.

Term in Equation	PROBABILITY OF DEFECT OCCURRING	
	High probability	Low probability
P_d	Location South and West of the Lancaster -Chelmsford line (except Devon and Cornwall)	Location North and East of the Lancaster-Chelmsford Line.
	High rainfall/windspeed index	Low rainfall/windspeed index
	Near coast	Away from coast
	Poor building ground	Good building ground
	Inadequate design for site, movement, etc.	Well designed for site, movement, etc.
	Lack of systematic supervision	Systematic supervision
	Poorly controlled critical operations	Well controlled critical operations
	Poorly stored materials	Well stored materials
	Loss of labour to other industries	Depression and lack of alternative employment
	Use of defective materials and components	Use of non-defective materials and components
	Central heating causing movement defects	No central heating
	Location in the West	Location in the East
P_e	Limited company builder	Non-limited builder
P_n	Small builder	Large builder
	Builder with short term policy	Builder with long term policy
	Much use of sub-contractors	Little use of sub-contractors
P_o	Purchaser knowledgable of building	Purchaser not knowledgable of building
P_a	Purchaser employs surveyor	Purchaser does not employ surveyor
P_o	Purchaser of high social class	Purchaser of low social class
P_a	High price property	Low price property
P_r	Purchaser buying his second house	Purchaser buying his first hous
P_c	Location in the South	Location in the North
	Perfectionist purchaser	Non-perfectionist purchaser
P_r	Financially suspect builder	Financially sound builder
P_n	Tardy after-sales service	Speedy after-sales service
P_j	Defect covered by Agreement	Defect not covered by Agreement

TABLE 34. SUMMARY OF CAUSAL FACTORS

PART V

RECOMMENDATIONS

THE PREVENTION OF DEFECTS

PREVENTION OF DEFECTS

IMPORTANT DEFECTS

130. Appendix A, Schedule 4, takes the important defects previously identified and proposes methods of prevention. The relevant clauses of the N.H.B.R.C. standard specification are examined and, in some cases, amendments proposed.

DIRECTED GENERAL EFFORT

131. This thesis identifies 375 different defect types. It is obviously unrealistic to give this as a list to the industry and say 'Prevent these'. Such a list is not comprehensible but it does contain valuable information. Each member or trade in the construction team can reasonably be expected to grasp up to ten key points on defect prevention. These can be used as the basis of posters, film strips, slides and other educational work for that particular discipline or trade. In Schedule 5 are given key points for designers, site supervision staff and each of the main building trades. The lists include all the items identified in this thesis as important defects together with some others drawn from the total list of 375 different defect types.

CHECKING THE HOUSE BEFORE HANDOVER

132. In Table 24 it was shown that 18.7% of all defects were items which it was possible to see as being wrong or incomplete before the house was handed over to the salesman or purchaser. These items have been worked up into a simple check list which a builder can use to see whether his house is really complete. This check list is given in Schedule 5 of the Appendix.

DESIGN FOR MOVEMENT

133. It is considered that the majority of minor movement defects can be eliminated by judicious use of cover-moulds at intersections such as wall/ceiling, frame /reveal plaster, skirting/floorboard. Alternatively, the joints between materials can be featured as gaps.

QUALITY CONTROL AND MANAGEMENT STRUCTURE

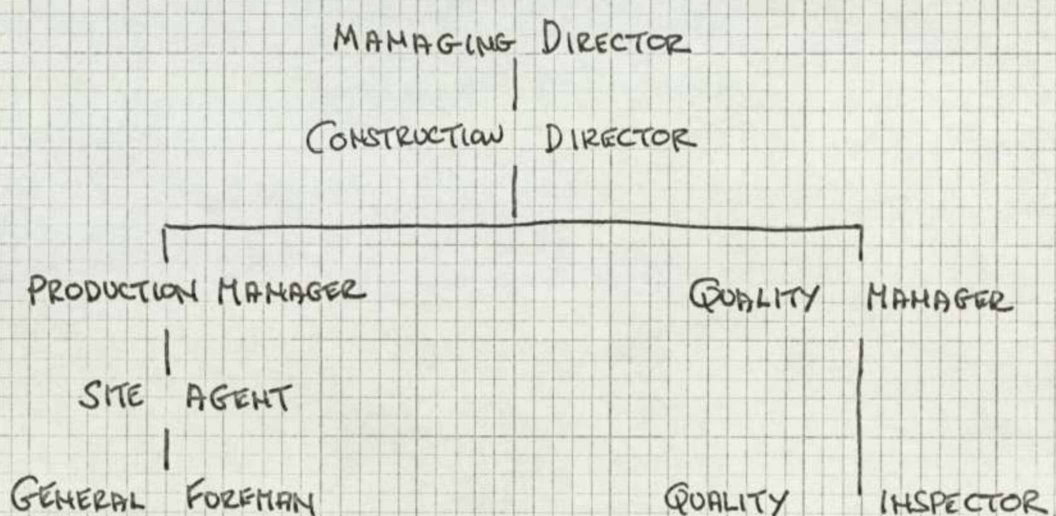
134. The Shepherd report has already been criticised in paragraphs 15 and 16 because it places quality control in a subordinate position to production. It was argued against Shepherd that quality inspection and control must report to a level of management above that responsible for day to day production and productivity. It is considered that it is fundamentally wrong to expect a man to beat cost and productivity targets, programme and co-ordinate the work of sub-contractors and, at the same time, be self-critical on quality matters. When sub-contractors are hard to obtain, it is all too easy and humanly understandable for an agent or general foreman to accept from them a standard of work which he really knows to be inadequate. Good and bad management structures are illustrated in Figure 16. The good structure shown in part (b) of the Figure shows the quality inspector and the quality manager independently answerable to the construction director.

135. In the case of a small firm where one person performs a range of functions, it is essential for the builder himself to disassociate from the production side and think in terms of quality from time to time. Speedy, low-cost production is not sufficient. Construction must be good if purchasers are to be satisfied and the good name of the industry upheld.

ROLE OF OUTSIDE INSPECTORS

136. Builders sometimes say that their houses are inspected by the local authority building inspector, by the N.H.B.R.C. inspector, by a building society surveyor and with all these inspections he can safely abrogate his responsibility for quality to them. This is a great error. In

(a) A BAD MANAGEMENT STRUCTURE.



(b) A GOOD MANAGEMENT STRUCTURE

FIGURE 1B MANAGEMENT STRUCTURES FOR SPECULATIVE HOUSE-BUILDING.

Table 24 of this thesis, all defects were allocated to members of the builder's team. Admittedly, inspectors and surveyors could and should have seen some of the defects and pointed them out. Prevention, however, is not their responsibility. Local authority inspectors have no powers over quality, they can only act within their statutory powers which limit them to structural, damp proofing, health and safety aspects. The N.H.B.R.C. inspection is a spot-check inspection and a contributory part of the guarantee and insurance scheme. It is not a substitute for the builder's own quality control. The building society surveyor is mainly concerned with the value and re-sale value of the property.

137. The argument for the absolute responsibility of the builder for all defects does not, however, make the outside inspector's job into a sinecure. Inspectors and surveyors must know where and why defects occur and be alert to their possible incidence and through knowledge of failures and complaints, be ready to intervene decisively to stop inadequate work at crucial points. The responsibility rests with the builder but the inspector must recognise when the builder is, in effect, out of control.

138. Nationally controlled inspectorates, particularly the N.H.B.R.C., should deploy their staffs in such a way that maximum effort is directed to the high risk areas shown in Figure 13. There is no special virtue in having uniformity of inspection level throughout the country.

PREVENTION OF COMPLAINTS

TOLERANCES FOR INITIAL BUILDING MOVEMENT

139. It was shown in paragraph 15 that initial building movement and matters of accuracy and general workmanship were the most controversial technical areas in complaints. Although a case has been made for eliminating movement defects by design, it is recognised that this may not be immediately acceptable to the building industry. Therefore, it is

necessary to define tolerances for the commonly occurring movement defects so that the areas of argument can be substantially reduced. Such tolerances should be written into the Agreement and Specification. Initially, such action would create more argument but, in the long term, the Agreement would be made definitive in a controversial area and the scope for complaint thereby reduced. Proposed tolerances are given in Schedule 6 of the Appendix. The manner of presentation is similar to that of the Greater Milwaukee standards shown in Schedule 1 of the Appendix.

TOLERANCES FOR BUILDING ACCURACY

140. The B.S.I. proposals for accuracy standards were discussed in paragraphs 31 and 32 . Some of the B.S.I. proposals were criticised as possibly being too onerous. This is a controversial area and precise tolerances need to be established and written into the Agreement and Specification. First it is necessary to measure houses under construction for accuracy and from that information, to derive maximum permissable tolerances. The measurement of standards of accuracy now being achieved would need to be based on a representative sample of all types and prices of house, a variety of builders and all geographical areas. This is a major area for future research. Schedule 7 of the Appendix gives an outline of the type of accuracy specification which should be produced and, by means of which, disputes could be objectively settled.

STANDARDS OF GENERAL WORKMANSHIP

141. There is a small residue of items which are unquantifiable. Examples of such items are the smoothness of wall plastering in general surfaces and around projections, such as fire surrounds or socket outlets, the general quality of paintwork and preliminary preparation, the difference between joinery upon which a fine panel saw has been used and that for which a rough saw has been used. In such cases it is not practical to give a quantitative tolerance for the determination of accuracy. The only way

of establishing a standard is to produce samples of work to the acceptable minimum standard and set them in a range with work a little better than acceptable and a little worse. Such standards must necessarily exist in one geographical centre. Professional photographers should be able to photograph 'the standards' so that they can be compared with work offered on building sites and decisions made as to whether or not the standard is complied with. Preliminary investigations into standards of this type are currently being carried out at the N.H.B.R.C. Training Centre in Preston.

LIABILITY PERIODS

142. The new house warranty scheme operated in Louisville, U.S., was discussed in paragraph 20. Under this scheme, certain defects are covered for longer periods than others. Some items being covered for the maximum period of one year, some for 90 days and some only if notified on takeover and some not at all. This is a rather complicated Agreement. Under the House Purchaser's Agreement in Britain, only maintenance items of minor haircracks and fair wear and tear are excluded from the builder's liability. It is considered, however, that the British scheme could profit from the Louisville one by exerting similar disciplines on purchasers so that minor and visual defects are brought forward very soon after purchase or not at all. A very simple rule could be that defects which are visible at the time of purchase must be reported to the builder within three months and that latent defects must be reported as soon as possible within the two year guarantee period. Such discipline would help to reduce the numbers of defects and would substantially curtail the minor items which professional surveyors could produce.

SPEEDY REMEDYING OF DEFECTS

143. It has become very apparent in this thesis (paragraph 105) that the major cause of friction between builders and purchasers is slowness

of response to agreed defects. Builders may delay carrying out work to avoid costs to themselves and in the hope that the purchaser will not persist in his request for it to be done. This is, however, not in accordance with the Agreement made between them. Education and exhortation have limited effects when the builder does not want to do the work. The only effective answer would seem to be a financial sanction against the builder. The choice of financial sanctions is between a retention and a fine. Building retentions are usually 5% of the contract sum and the money is retained for at least six months after completion of construction and sale. There is considerable pressure in the industry to reduce the large amounts of retention moneys held in respect of building contracts and there would certainly be resistance to introducing retentions into the private house-building field. The better course would seem to be for the N.H.B.R.C. to take powers to levy fines on builders who delayed more than a reasonable time in remedying defects. If such powers were taken, evidence from the purchasers could go before the Council and unless the builder could exonerate himself, he would be liable to a fine payable to the Council as well as for the cost of the remedial works being carried out by another builder. Such a scheme can be criticised as invidious but the problem is invidious. To be reasonable on the builders, the fine could be limited to a maximum of, say, £30 per house, just enough to hurt without being disproportionately oppressive.

DEFINITION OF A DEFECTIVE HOUSE

144. The idea was discussed in paragraph 13, that an article only becomes defective when it has a critical defect or when non-critical defects in aggregate amount to overall defectiveness. Demerits were given in paragraph 81 to house-building defects according to their inherent seriousness. It could be advocated that any defect in seriousness groups I or II should be remedied but that defects in seriousness

groups III and IV need only be remedied when their total demerit exceeds some reasonable value, such as 100 or 200 points. The purchaser would, in effect only be able to claim that he had either a critical defect or that his house contained such minor defects as would make it a defective house.

145. Experiments would have to be carried out to determine what a typically average demerit value was and any demerit value in excess of that would constitute a defective house. A risk is that purchasers would find more items to build up their demerits to the accepted value. This system could best be used after tolerances for all items have been satisfactorily defined as recommended in paragraphs 139 and 140 above.

RESEARCH INTO THE QUALITY OF NEW HOUSES

146. In the preceding paragraphs, three separate proposals have been made for research into the quality of new houses, namely the standards of accuracy to which houses are built, standards of general workmanship achieved to enable sample standards to be established and the total demerit ratings for the less serious types of defects to enable a normal demerit value to be ascertained. These three elements could be combined into one unified research project in which a representative sample of new houses throughout the country was measured for accuracy, checked against provisional quality standards and inspected to ascertain demerit values.

APPENDIX A

SCHEDULES

METROPOLITAN BUILDERS COMMITTEE OF GREATER MILWAUKEE

TOLERANCES FOR CARPENTRY AND PLUMBING DEFECTS

Defect No.	Common defect or problems	Acceptable tolerance on these defects	Builder repair responsibility
C1	Floor joist causing bow in top jamb of basement window	Building should be structurally sound and floor level on first floor (i.e. within $\frac{1}{4}$in. of level in a 32in. area). Window should not bind due to jamb deflection.	Builder to make structural repairs to correct.
C2	Squeak in floors	Should be unobjectionable to owner within reasonable repair responsibility.	Locate squeak and face nail, screw floor from below, or wedge cedar shingle with feathered edge between the floor joist and blind floor in basement at point of squeak.
C3	Uneven floors	Floor should not be more than $\frac{1}{4}$in. off level in 32 in. or not more than 1/240 of span with unfinished ceiling below or 1/360 of span with finished ceiling below in any room.	Builder to repair to meet above standard.
C4	Cabinet gap between soffit or wall.	Acceptable tolerance $\frac{1}{8}$in. provided the cabinet installation is structurally secure.	Builder to correct and, if part of his contract, retouch repaired surfaces as closely as possible.
C5	Window check rails not even or flush.	Acceptable tolerance is 3/16in.	Builder to correct.
P1	Leakage of any kind from piping.	No leaks of any kind should exist in any soil, waste, vent, or water pipe except where soil pipe leaks due to flooded or inoperative septic system.	Builder shall make necessary repairs to eliminate leakage.
P2	Faucet leak or valve leak.	No valve or faucet should leak because of defects in either material or workmanship.	Builder shall repair or replace the leaking faucet or valve, unless leakage is due to a defective washer. Washer replacement is normally a homeowner's maintenance problem.

P3	Fixtures do not hold water.	Stoppers on fixtures should retain water for a sufficient length of time to accomplish the fixture's intended use.	Builder to correct until fixture holds water to meet acceptable tolerance.
P4	Chipped, warped or defective plumbing fixtures and brass goods.	In case of questions between owner and builder as to the seriousness of the defect, the fixtures should be inspected by the manufacturer's representative and judged according to their manufacturing standards.	Builder shall replace any fixture or fitting which is outside accept-table standards as de-fined by the manufacturer. In the case of chipping the builder shall replace the fixture if the chipping is noted on the occupancy inspection. After occupancy the responsibility for chipped fixtures is the owner's.
P5	Stopped-up sewers, fixtures, and drains.	Sewers, fixtures and drains should operate properly to accomp-lish their intended function.	Because sewers, fixtures and drains can easily be clogged through the owner's negligence, the builder shall make the necessary repairs to put the sewer in proper operating conditions. However, if the problem which caused stoppage of the sewer can be shown to be due to owner's negligence, the owner shall assume the cost of the repair.
P6	Waste disposal unit does not operate properly.	Disposal unit must accomplish its intended function.	Builder shall repair disposal unit, but as in item 5, if it can be shown that malfunction is due to owner's negligence the owner shall pay bill.
P7	Cracked cement laundry tubs.	Laundry tubs should not leak.	Builder has no repair responsibility on tubs unless the defect was noted on the occupancy inspection. Due to improper owner filling of tubs which causes uneven heating, in contradiction to the manufacturer's caution on the tubs, these tubs are subject to cracking.

Table 3 (cont'd)

P8	Noisy water pipes	There should be no objectionable water sounds, except those due to flow through the pipes, or where local water pressure exceeds 65 pounds per square inch.	Builder should remove noises not due to the flow of water.
P9	Sump pump does not operate	Sump pump should reasonably be expected to perform for a one year period satisfactorily, unless unusual conditions such as under-ground springs or highwater table are encountered.	Builder shall repair or replace malfunctioning sump pump.

IMPORTANT DEFECTS

Defect Group	Frequency List	Cost/ Frequency List	Seriousness/ Frequency List
Structural inadequacy		Floor fill settlement. Subsidence Retaining walls not provided.	
Damp penetration	Around chimneys	Water on oversite. Missing D.P. membranes. Cavity bridged.	Cavity bridged. At jambs of openings. Around chimneys. Broken/loose vertical tiles. Provide weather bar. Around door.
Inadequate mechanical parts	Pumps, switches, valves and thermostats.		Pumps, switches, valves and thermostats.
Inadequate fixings and jointing.	Leaks in pipes, radiators and boilers. Loose or cracked floor tiles. Loose glass/ putties.		Leak at gutter joints. Non-alignment of gutters. Loose pipes/water hammer. WC soil pipe leak General leaks in plumbing. Leaks in pipes, radiators and boilers. Loose or cracked floor tiles.
Premature breakdown of materials	Breakdown of external paintwork		
Nuisance and safety and health risks		Faulty flue linings	

Defect Group	Frequency List	Cost/ Frequency List	Seriousness/ Frequency List
Non-provision of Items and incomplete work.	External paintwork Mastic to windows Internal paintwork Plaster making good.		Mastic to window Wire balloon (so
Damaged and broken items.			
Initial movement of building	Bath/tiling gap Ill fitting external doors. Ease external doors Movement of window sashes. Cracks in wall plaster. Flaking plaster Loose wall tiles	Joist/partition shrinkage	Warped external door. Joist/partition shrinkage
Building inaccuracies	Ponding falls and levels to drives. Rough plaster/ uneven wall areas.		Ponding falls an levels to drives
General unacceptable workmanship.	Rough internal paintwork.		
Various			Manholes - level loose or cracked renderings.

TECHNICAL DISCUSSION OF IMPORTANT DEFECTS

(Note: Specification criticisms relate to the NHBRC Standard Specification)

DEFECT	FLOOR FILL SETTLEMENT
INCIDENCE	Found in 1.5% of dispute cases. Important because of cost.
SYMPTOMS	Caving in of floor and cracking of floor finish. Slope on floor. Gap between skirting and floor finish.
CAUSES	Use of soft material as underfill which compacts or rots and causes the floor to sink. Use of deep underfill which is not well-consolidated in 6in.-9in. layers; common on sloping sites where the depth of underfill varies from, say, 9in. at one end to 24in. at the other.
PREVENTION	Use of timber suspended floors. Use of reinforced concrete suspended floors. The use of dry piers in the depth of the fill on a 6ft. grid. Greater supervision care.
SPECIFICATION CRITICISM	Clause Ex.14 requires underfill to be consolidated in 6in.-9in. layers. A cautionary note should be added as follows:- 'Note: Builders are reminded that if underfill is not adequately consolidated and its total depth exceeds 9in.-12in. severe damage to floor slabs may result. Where deep fill is required, it may be preferable to use a suspended reinforced concrete or timber floor construction'.

DEFECT	SUBSIDENCE
INCIDENCE	Found in 1.2% of dispute cases. Important because of cost.
SYMPTOMS	(a) Breaking away of attached structures, such as porches or garages. (b) Structural cracks in walls.
CAUSES	(a) Differential settlement. (b) Foundations inadequately designed for the ground conditions.
PREVENTION	(a) Keep foundations at uniform depth, especially in shrinkable soil. (b) Greater design care.
SPECIFICATION CRITICISM	(a) Add to clause Ex.9 a statement to the effect that the depths of adjoining foundations must be such that differential settlement does not occur. (b) Insert in the Ex section an additional requirement as follows:- 'Before designing foundations, the builder shall acquaint himself with all available information concerning the stability and bearing capacity of the ground. Geological maps and local sources of information should always be consulted and exploratory borings made if necessary. Particular attention should be paid to made up ground. The Council may require evidence of adequate preliminary ground explorations.'

<u>DEFECT</u>	<u>RETAINING WALL NOT PROVIDED</u>
INCIDENCE	Found in 1% of dispute cases. Important because of cost.
SYMPTOMS	Soil erosion. Collapse of drives and paths into adjoining gardens at a lower level. In severe cases, the stability of the house may be at risk.
CAUSES	Failure on the part of the designer to appreciate the levels and soil movements that will occur on sloping or terraced sites. Financial pressures on low cost developments on bad sites.
PREVENTION	Greater design care.
SPECIFICATION CRITICISM	Clause De6(c) is not specific. The following paragraph should be added to it:- 'Retaining walls shall be provided where necessary to support the edges of drives and paths when the adjoining ground is at a higher or lower level'.

DEFECT	WATER ON OVERSITE
INCIDENCE	Found in 1.5% of dispute cases. Important because of cost.
SYMPTOMS	Water standing under a suspended floor on the oversite concrete. Often revealed when the first purchaser is selling the house and it is being surveyed. Exceptionally, there may be a dank smell.
CAUSES	Water penetration of the oversite concrete or the foundation brickwork, due to waterlogged ground or a water course. Commonly occurs when the house is on a hillside and surface water follows the profile of the hill beneath the surface.
PREVENTION	The provision of an adequate land drainage system to divert ground water from the part of the site immediately surrounding the house.
SPECIFICATION CRITICISM	None. Clause Dr.29 is adequate.

DEFECT	MISSING DAMP PROOF MEMBRANE
INCIDENCE	Found in 0.8% of dispute cases. Important because of cost.
SYMPTOMS	Rising floor tiles with damp beneath. Uniform dampness over the whole floor area. Failure to dry out after removal of tiles and with ventilation and heating. (Note: Non-uniform damp in the floor may indicate a pipe leak or a tear or gap in the membrane. Uniform damp which disappears with ventilation and heating would indicate condensation.)
CAUSES	Failure to provide a damp-proof membrane as required by Building Regulations and N.H.B.R.C. Specification. Failure in the supervision of critical operations. Later inspection should have aroused suspicions due to absence of any projecting parts of the membrane, no upstand from the membrane to the wall D.P.C. or signs of bitumen or asphalt if it was to have been an applied D.P.C.
PREVENTION	Care and observation.
SPECIFICATION CRITICISM	None. Clause Co.29 is adequate.

DEFECT	CAVITY BRIDGED
INCIDENCE	Found in 2.5% of dispute cases.
SYMPTOMS	(a) Damp area on wall surface above the horizontal D.P.C. (b) Small circular damp patches which increase and decrease in size with wet and dry periods.
CAUSES	(a) Cavity blocked with mortar or mortar standing on a D.P.C. tray or trunking. (b) Wall ties sloping inwards or spots of mortar on wall ties.
PREVENTION	Greater skill and care in brickwork.
SPECIFICATION CRITICISM	None. Clause Br.26 is adequate.

DEFECT	DAMP ENTRY AT JAMBS OF OPENINGS
INCIDENCE	Found in 3.5% of dispute cases.
SYMPTONS	Damp on door or window reveals next to the frame which is proved by the use of a moisture meter to be other than surface condensation. The damp patches will normally be immediately adjoining the frame.
CAUSES	Failure to isolate the internal skin of the cavity wall from the external by the use of either vertical D.P.C.'s, rebated reveal constructions or complete isolation of the two skins.
PREVENTION	Use of a 6in. wide vertical D.P.C. and not 4½in. Use of rebated reveals. Cavity not closed at all except by frame.
SPECIFICATION CRITICISM	Clause Br.27(d) should be re-drafted as follows:- 'The sides of openings shall be so constructed as to prevent the passage of damp to the interior. Where a vertical damp proof course is used, it shall be 6in. wide and be tacked to the edge of the frame. Rebated or open reveal construction should be used when required in areas of high rainfall or exposure. Where a gap or more than ⅛in. occurs between the frame and the brickwork, it shall be pointed up with a non-setting mastic'.

DEFECT	DAMP ENTRY AROUND CHIMNEY
INCIDENCE	Found in 4.2% of dispute cases.
SYMPTOMS	Damp on the ceiling around the chimney breast. Damp on the breast wall.
CAUSES	Failure of the chimney/roof flashing system to keep out blown rain.
PREVENTION	(a) On sites of normal exposure, greater care in execution of normal flashing details. (b) On exposed sites, the use of special details such as lead tray, second DPC or vertical DPC lining joining the DPC's. (Note: In the case of normal chimney flashing, it is impossible to tell visually whether the workmanship is adequate. If there is any doubt, a hose test should be applied.)
SPECIFICATION CRITICISM	Clause Rf.24(g), Rf.25(f) and Rf.26(d) are too vague. The following clause should be substituted:-

'Weatherproofing around chimneys

A system of damp proof course, soakers, cover flashings, aprons and gutters appropriate to the roof covering material and adequate to prevent the passage of damp to the interior shall be provided. Where warranted by local rainfall and exposure conditions, special precautions shall be taken, such as the provision of lead trays, a second D.P.C. or vertical D.P.C. linings to the face of the stack.'

DEFECT	BROKEN OR LOOSE VERTICAL TILES
INCIDENCE	Found in 2.7% of dispute cases.
SYMPTOMS	Vertical cladding tiles shown as being broken or loose; this could lead to damp entry and the decay of wall studs or studs in dormer cheeks.
CAUSES	Failure to nail each tile with two nails as required by the N.H.B.R.C. Specification. Damage by ladders.
PREVENTION	Greater care.
SPECIFICATION CRITICISM	None. Clause Rf.25(h) is adequate.

DEFECT	WEATHER BOARD NOT PROVIDED TO DOOR
INCIDENCE	Found in 2.5% of dispute cases. (Inadequate weather boards found in a further 2.3% of cases).
SYMPTOMS	Water on floor just inside the door in wind/rain conditions normal for the site.
CAUSES	Non-provision of a weather board in conditions where one is necessary to keep rain out. (The cause of weather boards being inadequate is usually that the board is cut short and does not meet the jamb of the frame.)
PREVENTION	Provision of weather board.
SPECIFICATION	Clause Cj.57 requires weather bars to inward opening doors. It should be extended to require weather boards. (Note: Although not included in the schedule of important defects, the inadequacy of weather bars is another defect. Cj.57 should also refer to local practices on the use of double weather bars.)

DEFECT	DAMP ENTRY AROUND DOOR
INCIDENCE	Found in 2.9% of dispute cases.
SYMPTOMS	Rain blown in around the jambs and head of door.
CAUSES	Excessive gap between door and frame.
PREVENTION	Deeper rebate sections and greater care in the fitting of doors. Use of weather strip. Provision of a protective porch. (Note: This could not be required of the builder under the terms of the Agreement, unless included in his design for the house; but in positions of extreme exposure it is the only satisfactory way of excluding blown rain.)
SPECIFICATION CRITICISM	None. Clause Cj.54(a) is adequate.

DEFECT	FAULTY PUMPS, SWITCHES, VALVES AND THERMOSTATS IN CENTRAL HEATING INSTALLATIONS.
INCIDENCE	Found in 4.5% of dispute cases.
SYMPTOMS	Failure in operation of the component. Shutdown of the heating system.
CAUSES	Normally a manufacturing deficiency in the component.
PREVENTION	-
SPECIFICATION CRITICISM	The Hv section includes no specifications for heating hardware. Where British Standards exist for these items, they should be specified.

DEFECT	LEAK AT GUTTER JOINT
INCIDENCE	Found in 3.6% of dispute cases.
SYMPTOMS	Dripping from joint.
CAUSES	Failure to make the joint in accordance with the manufacturer's instructions. Joint loosens slightly, causing grit from roof tiles to enter and force it open still further.
PREVENTION	Greater skill and care.
SPECIFICATION CRITICISM	British Standards should be specified for plastic rainwater goods. Clauses Rf.20 and Pb.69 should include an additional paragraph as follows:- 'Proprietary gutter and down pipe systems shall be used strictly in accordance with the manufacturer's instructions. Joints in gutters and down pipes shall be so constructed as to be free of leaks. Sufficient gutter brackets shall be provided to enable the gutters to fall evenly to the outlet points without sagging.' (See defect 14).

DEFECT — NON-ALIGNMENT AND OVERFLOW OF GUTTERS

INCIDENCE — Found in 3.4% of dispute cases.

SYMPTOMS — Overflow or cascading from the gutter.

CAUSES

(a) Fall of the gutter away from and not towards the R.W.P.

(b) Dip in the run of gutter preventing water from reaching the R.W.P.

(c) Occasionally, undersizing.

PREVENTION

(a) Skill and care in execution.

(b) Use of more brackets.

(c) Greater design care.

SPECIFICATION CRITICISM — As for defect 13.

DEFECT	LOOSE PLUMBING PIPES AND WATER HAMMER
INCIDENCE	Found in 3.6% of dispute cases.
SYMPTOMS	Unacceptable water hammer after water has been drawn off.
CAUSES	Oscillations in the pipe.
PREVENTION	Use of more pipe clips. A maximum distance of 4ft. between clips is normally recommended.
SPECIFICATION CRITICISM	The Pb section does not refer to pipe clipping. An additional clause should be inserted incorporating a schedule of maximum centres for clipping according to diameter and location of the pipe. Consideration should be given to specifying a water pressure below which water hammer is not acceptable. (See Greater Milwaukee clause P.8 in Schedule 1 of this thesis).

DEFECT	LEAK AT JOINT OF W.C. OUTLET TO SOIL PIPE
INCIDENCE	Found in 2.5% of dispute cases.
SYMPTOMS	Water pooling on floor by W.C. outlet and dampness around the joint.
CAUSES	(a) Lack of skill and care in the making of the joint. (b) Differential movement between the floor (if timber, subject to shrinkage), the rigid pan and the soil pipe.
PREVENTION	Greater care.
SPECIFICATION CRITICISM	The following additional requirements should be incorporated in Pb.50:- 'Joints between W.C. pans and soil pipes shall be carried out in accordance with the pipe manufacturer's recommendations and in such a way that leakage does not occur.'

DEFECT	GENERAL LEAKS IN PLUMBING
INCIDENCE	Found in 3.4% of dispute cases.
SYMPTOMS	Minor leak at a coupling or joint to a fitting. Corrosion of pipe causing major leak.
CAUSES	Bad workmanship and failure to test adequately. A bi-metallic problem. Chemical action on the exterior of the pipe by ground or adjoining materials. Use of thin-wall or sub-standard pipe.
PREVENTION	Greater skill and care. Knowledge of chemical composition and likely actions of local water.
SPECIFICATION CRITICISM	In the general clause for pipe fixing suggested for defect 15, an additional comment should be included relative to the carrying out of jointing in such a way that leaks do not result.

DEFECT	LEAKS IN HEATING PIPES, RADIATORS AND BOILERS
INCIDENCE	Found in 4.3% of dispute cases.
SYMPTOMS	Visible leak at a coupling or joint to a fitting. Corrosion of pipe, causing a major leak. Saturated floor screed indicating a hidden leak.
CAUSES	Bad workmanship and failure to test adequately. Entry of oxygen into a closed system. A bi-metallic problem. Chemical action on the exterior pipe by cementitious materials. Use of thin-wall or sub-standard pipe.
SPECIFICATION CRITICISM	A clause should be included in the Hv section similar to that proposed for the Pb section under defect 17.

DEFECT	LOOSE OR CRACKED FLOOR TILES
INCIDENCE	Found in 4.5% of dispute cases.
SYMPTOMS	(a) Rising floor tiles.
	(b) Cracking of floor tiles.
CAUSES	(a) Inadequate adhesive.
	Damp from condensation, pipe leak or rising damp.
	(b) Tiles laid on dirty or uneven surface.
PREVENTION	(a) Greater skill and care.
	(b) Clean and level surface before laying tiles.
	Refuse to lay tiles on unacceptable surfaces.
SPECIFICATION CRITICISM	None. Clause Pv.59 is adequate.

DEFECT	LOOSE OR DEFECTIVE PUTTIES
INCIDENCE	Found in 4.3% of dispute cases.
SYMPTOMS	Putty comes away from glass and frame. Excessive finger marks in and untidyness of putties.
CAUSES	Glazing wet frames. Lack of skill and care.
PREVENTION	Greater skill and care.
SPECIFICATION CRITICISM	The G1 section does not refer to general workmanship matters. An additional clause is required to include the above points.

DEFECT	BREAKDOWN OF EXTERNAL PAINTWORK
INCIDENCE	Found in 6% of dispute cases. (Specifically on cills 3.1% and generally in 4.6% of cases. Aggregate 6%).
SYMPTOMS	Cockling of paint Loss of adhesion, particularly on cills and claddings. } occurring prematurely
CAUSES	(a) Painting on wet timber (b) Insufficient body in the paint system due to watered down or low quality material. (Note: The N.H.B.R.C. Standard Specification requires a primer, one undercoat and one finishing coat. This is regarded as adequate to give a two-year protection).
PREVENTION	(a) Site control (b) Use of adequate quality paint.
SPECIFICATION	Clause Pp.8 is adequate. But there is no British Standard for any paint used in house-building today. The only B.S. for paint is that for lead-based ones.

DEFECT	EXTERNAL PAINTWORK INCOMPLETE
INCIDENCE	Found in 6.5% of dispute cases.
SYMPTOMS	Gloss coat missed from a sash or member of a frame. Hidden surface such as a cill soffit not painted. Backs of bargeboards or fascias not primed.
CAUSES	Lack of care in workmanship and checking.
PREVENTION	Use of completion check list (Schedule 5).
SPECIFICATION CRITICISM	An additional clause should be inserted in the Requirements section as follows:-

'Completion

The builder shall ensure that the whole of the work in the construction of the dwelling is completed before it is handed over to the purchaser. Making good after service trades and the entire completion of decorations are particularly important. Where it is desired to give occupation before the final surfacing of drives or similar items, the purchaser shall be so advised.'

DEFECT	**MASTIC POINTING TO WINDOW FRAMES NOT DONE OR INCOMPLETE**
INCIDENCE	Found in 6.3% of dispute cases.
SYMPTOMS	Excessive gap between frame and brickwork.
CAUSES	Lack of skill and care in brickwork. Failure to check house before handover.
PREVENTION	Use of completion check list (Schedule 5).
SPECIFICATION CRITICISM	As for defect 7.

DEFECT	INTERNAL PAINTWORK INCOMPLETE AND COATS MISSED
INCIDENCE	Found in 5.6% of dispute cases.
SYMPTOMS	Gloss coat missed from a sash or frame member. Hidden surface such as a window board soffit not painted. Obscure items such as an airing cupboard ceiling not decorated.
CAUSES	Lack of care in workmanship and checking.
PREVENTION	Use of completion check list (Schedule 5).
SPECIFICATION CRITICISM	As for defect 22.

DEFECT	INCOMPLETE PLASTER MAKING GOOD
INCIDENCE	Found in 4.8% of dispute cases.
SYMPTOMS	Plaster not made good around waste pipes. Plaster not made good around pipes in airing cupboards ceilings and similar.
CAUSES	Failure to return after other trades. Lack of care in checking.
PREVENTION	Use of completion check list (Schedule 5)
SPECIFICATION CRITICISM	As for defect 22.

DEFECT	WIRE BALLOON MISSING FROM SOIL PIPE
INCIDENCE	Found in 3.3% of dispute cases.
SYMPTOMS	Wire balloon missing.
CAUSES	Lack of care in checking.
PREVENTION	Use of completion check list (Schedule 5).
SPECIFICATION CRITICISM	As for defect 22.

DEFECT	GAP BETWEEN BATH AND WALL TILING ABOVE
INCIDENCE	Found in 5.3% of dispute cases.
SYMPTOMS	Appearance of the gap.
CAUSES	Settlement due to the weight of a filled bath. Joist shrinkage.
PREVENTION	Load distribution by placing bath feet on bricks or tiles. Masking of the inevitable gap with a plastic cover strip.
SPECIFICATION CRITICISM	Clause Pb.49 requires the joint to be watertight which, as a requirement, is adequate. However, the point would be made more forcibly by the addition of a note as follows:-

'Note:- Builders are advised that when a bath is located on a joisted floor, the weight of the bath and shrinkage in the joists are likely to produce a gap which will render the joint unwatertight. Precautions should be taken against this, for example, by the use of proprietary masking strips.'

DEFECTS	ILL-FITTING INTERNAL DOORS
INCIDENCE	Found in 10% of dispute cases. (3.6% of cases relating to kitchens, bathrooms, and airing cupboards, 5.1% of cases relating to living and bedrooms, 4.4% of cases room unspecified, aggregate 10%).
SYMPTOMS	Excessive or unequal margins around the door. Binding.
CAUSES	Lack of skill and care. Shrinkage due to excessive moisture in door or over-fast drying out.
PREVENTION	Greater care in workmanship and storage. Definition of tolerances (Schedule 6).
SPECIFICATION CRITICISM	Clause Cj.56 is adequate, but a specific tolerance should be added.

DEFECT	ENTRANCE DOOR REQUIRING EASING
INCIDENCE	Found in 4.9% of dispute cases.
SYMPTOMS	Door does not shut easily due to binding or twisting. Draught.
CAUSES	Swelling in winter. Hygro-thermal stress due to differences in internal and external humidities.
PREVENTION	Use of more stable and robust door. Minimised movement by careful storage before fixing. Definition of tolerances (Schedule 6).
SPECIFICATION CRITICISM	Clause Cj.10 refers to the BS for doors. The forthcoming revision of this should be adequate. Cj.65 is adequate for storage.

DEFECT	WARPED EXTERNAL DOOR REQUIRING REPLACEMENT
INCIDENCE	Found in 2.6% of dispute cases.
SYMPTOMS CAUSES PREVENTION SPECIFICATION CRITICISM	As for defect 29, except that the symptoms are more severe

DEFECT	MOVEMENT OF WINDOW SASHES
INCIDENCE	Found in 5.3% of dispute cases.
SYMPTOMS	Window does not shut easily due to binding or twisting. Gap around the window; draught.
CAUSES	Seasonal swelling and shrinkage. Hygrothermal stress due to difference in internal and external humidities.
PREVENTION	Use of more stable and robust sashes. Minimised movement by careful storage before fixing. Definition of tolerances (Schedule 6).
SPECIFICATION CRITICISM	Cj.12 refers to the BS for windows. The forthcoming revision of this should be adequate. Cj.65 is adequate for storage.

DEFECT	CRACKS IN WALL PLASTER (IN THE PLANE, NOT AT INTERSECTIONS)
INCIDENCE	Found in 5.5% of dispute cases. (4.8% of cases relative to general areas and 2.8% of cases in reveals, aggregate 5.5%).
SYMPTOMS	Appearance of cracks larger than hair cracks.
CAUSES	Shrinkage in blockwork beneath. Differential shrinkage between rendering and setting coats. Over-fast drying out.
PREVENTION	Protection of blocks against rain before fixing. Definition of tolerance (Schedule 6).
SPECIFICATION CRITICISM	A new clause is needed in the Br section to cover the use of lightweight blocks. The manufacturers of these blocks have a number of specific recommendations. Such a clause should include reference to the need to keep the blocks dry before and after construction.

DEFECT	FLAKING WALL PLASTER
INCIDENCE	Found in 4.6% of dispute cases. (4.1% relative to flaking around openings, 4.6% relative to general surface, aggregate 6%).
SYMPTOMS	Flaking off of the top plaster coat in small areas.
CAUSES	(a) Insufficient thickness of plaster over conduits and cable sheathings. (b) Shrinkage in plaster or blockwork beneath. (c) Over-fast drying out.
PREVENTION	(a) Chasing in. (b) Protection of materials against rain.
SPECIFICATION CRITICISM	None. El.7 and Pt.20 are adequate, but see defect 32.

DEFECT	LOOSE WALL TILES
INCIDENCE	Found in 4.5% of dispute cases.
SYMPTOMS	Tiles falling off.
CAUSES	Use of wrong or insufficient mastic, Differential shrinkage between blockwork, plaster and tiles.
PREVENTION	Following of the manufacturer's instructions on adhesion. Protection of materials against rain.
SPECIFICATION CRITICISM	Pt.40 is adequate for the adhesion process. As for defect 32 on protection of blockwork.

DEFECT JOINT/PARTITION SHRINKAGE

INCIDENCE Found in 2.8% of dispute cases.
Important because of cost.

SYMPTOMS Appearance of gap between partition head and ceiling.
Less commonly, appearance of gaps at sides or soffits of partitions.
Binding of doors in partitions.
Visible sag over stairwells.

CAUSES Shrinkage and deflection in deep long span floor joists. Joists not supported off ground floor partitions to reduce movement and depth.
Load concentration, e.g. airing cupboard and tank, over trimmer and trimming joists, adding to the deflection.
Rigid trussed roof structures not moving in sympathy with partitions and joists beneath.

PREVENTION Design for joist of 8in. maximum depth.
Avoid load concentrations, which add to deflection and shrinkage movement.

SPECIFICATION CRITICISM An additional clause should be included in the De section on 'Design for Movement'. This should be in the form of recommendations rather than requirements. It should cover the points relative to this defect, i.e. minimising joist depths by the use of an adequate system of load bearing partitions.

DEFECT	PONDING AND UNEVEN OR INCORRECT FALLS AND LEVELS TO DRIVES AND PATHS
INCIDENCE	Found in 5.3% of dispute cases.
SYMPTOMS	Drive or path falls towards instead of away from building. Ponding in the area of drive or path.
CAUSES	Lack of skill and care. Inadequate consolidation of the underfill. Inadequate consolidation of ground after back filling of trenches before laying drive or path.
SPECIFICATION CRITICISM	Pv.65(a) should include reference to the backfilling and consolidating of trenches beneath drives, and paths. Pv.71 should specify the drives and paths should fall away from buildings.

DEFECT	ROUGH PLASTER/UNEVEN WALL AREAS
INCIDENCE	Found in 4.2% of dispute cases.
SYMPTOMS	Visual unacceptability of the plaster surface.
CAUSES	Inadequate use of rules. Scarring of finished surfaces with trowels. Damage by the builder.
PREVENTION	Greater skill and care in plastering. Greater skill and care in rubbing down and filling before decoration. Check against standard approved samples of workmanship.
SPECIFICATION CRITICISM	The present Pt.34 should become the final paragraph of a general clause on standard of finish. Such a clause should include practical points, such as those indicated above under Causes. Pp.6 is adequate to cover preparation prior to decoration.

DEFECT	ROUGH INTERNAL PAINTWORK
INCIDENCE	Found in 6.7% of dispute cases.
SYMPTOMS	Runs in the paint. Brush marks in the paint. Paint applied over dirt and grit. Rough surface of woodwork.
CAUSES	Lack of sanding and filling. Lack of skill and care in paint application.
PREVENTION	Greater care. Check against standard approved samples of workmanship.
SPECIFICATION CRITICISM	There is no specification at all for internal paintwork. Pp.10, external paintwork, is adequate and should apply to internal paintwork as well.

DEFECT	MANHOLES AT WRONG LEVEL, OR WITH RENDERINGS LOOSE OR CRACKED
INCIDENCE	Found in 2.0% of dispute cases.
SYMPTOMS	(a) Manhole above or below adjoining drive or path or ground levels. (b) Loose or cracked renderings.
CAUSES	(a) Failure to check levels before building manhole or to adjust completed manhole when found wrong. (b) Lack of skill and care.
PREVENTION	(a) Greater care in checking levels of completion. (b) Greater skill and care.
SPECIFICATION CRITICISM	Dr.15 should include an additional clause to the effect that inspection chambers should be level with surrounding areas. References to rendering are adequate.

PREVENTION OF DEFECTS:

KEY POINTS FOR THE CONSTRUCTION TEAM.

POINTS FOR DESIGNERS

1. Ensure that foundation design is adequate; where necessary carry out ground exploration.

2. On sloping sites, ensure that retaining walls are provided where they are required.

3. Allow for sufficient surface water drainage around the house.

4. Calculate joist sizes with care and ensure that these are most clearly stated on drawings so that mistakes cannot occur on site.

5. Detail doors to prevent damp entry especially at the foot.

6. Design floors and partitions to prevent distortion due to shrinkage.

7. Detail for shrinkage either by specifying cover moulds or by making a feature of gaps.

8. Give an adequate detail at the junction of cladding with cross walls.

9. On split level or sloping sites consider using suspended floors in preference to deep fill.

10. Detail window and other similar D.P.C.s for the local climate.

POINTS FOR SITE MANAGEMENT

1. Ensure that fill beneath floor slabs and under drives is properly compacted.

2. Avoid difference in foundation levels leading to structural movement.

3. Check D.P.C.s to heads and jambs of door and window openings.

4. Minimise shrinkage by protecting blocks, plasterboard, timber and joinery from rain and damp, before, during and after installation.

5. Do not accept finishes that are too rough, especially decoration.

6. Check that all work in the roof space is complete.

7. Do not leave damaged doors, sanitary fittings or windows; change them.

8. Check for missed top coats of paint in isolated places, especially around windows.

9. Check that all making good is done around pipes etc.

10. Make sure that drives, boundary walls and garages are complete and to the same standard as the house.

POINTS FOR BRICKLAYERS

1. Keep cavities clean.

2. Do not cut short vertical D.P.C.s and D.P.C. trays.

3. Install fires and surrounds strictly in accordance with the manufacturer's instructions.

4. Fill up putlog holes.

5. Make a good job of pointing.

6. Make good around waste pipes.

7. Ensure bricks are adequately bedded.

8. Make good party walls up to the roof line.

9. Fill perpends, especially in party walls.

10. Clean off mortar splashes before leaving the job.

POINTS FOR CARPENTERS.

1. Secure frames and linings to walls adequately.

2. Ensure weather boards and bars are close fitting.

3. Avoid gaps between eaves, soffits and walls.

4. Fix skirting close to walls and floorboards.

5. Ensure adequate fixing of door locks and furniture.

6. Do not hang damaged doors.

7. Re-cover timber and joinery stacks after taking what you need from them.

8. Where there are excessive gaps between frames and brickwork, point up with mastic.

9. Ensure that doors are properly fitted.

10. Check roof frames and joist sizes for structural adequacy.

POINTS FOR ROOF TILERS (INCLUDING GUTTER FIXING).

1. Do not tear the sarking; if you do, patch or replace before fixing the tiles.

2. Extend the sarking into the gutter.

3. Make sure cement torching is complete.

4. Do not leave cracked tiles; replace any you crack, vertical tiles as well as those on the roof.

5. Adequately dress and tuck in chimney flashings and provide cover flashings.

6. Ensure upstands to flat roofs are damp proof.

7. Fit gutters to even falls to outlets.

8. Gutter joints must be properly made.

9. Provide adequate flashings arounds S.V.P.s.

10. Provide the required number of nails to tiles.

POINTS FOR PLUMBERS AND HEATING ENGINEERS.

1. Fix basins securely.

2. Ensure the joint of WC outlet to soil pipe is well made.

3. Prevent leaks on sink traps and wastes.

4. Do not weaken joists by cutting them away for pipes to pass.

5. Lag pipes in the roof where there is risk of freezing.

6. Do not fit damaged sanitary ware.

7. Provide enough pipe clips.

8. Ensure that all joints, but especially those under floors, are properly made, and do not leak.

9. Prevent leaks at joints of pipework to radiators.

10. Do not leave tank lids and tank insulation unfixed or incomplete.

POINTS FOR PLASTERERS AND FLOOR TILERS.

1. Make good around pipes always.
2. Do not leave wavy ceiling lines.
3. Wall surfaces must be smooth and even.
4. Use compatible materials for successive plaster coats. Follow the manufacturer's recommendations.
5. Apply glazed wall tiling in accordance with the tile or mastic manufacturer's instructions.
6. Do not leave cracked wall tiles.
7. Ensure wall tiling is complete, including making good around pipes.
8. Do not lay floor tiles on dirty or uneven screeds.
9. Ensure adequate key for floor screeds.
10. Do not leave loose or cracked floor tiles; replace them.

POINTS FOR PAINTERS

1. Do not paint on cills or claddings when they are too wet.
2. Ensure puttying is carried out correctly.
3. Seal knots and metal embedded in plaster to prevent staining through.
4. Do not decorate on plaster when it is too wet.
5. Check woodwork to see that the final coat has been applied throughout, especially near windows.
6. Adequately rub down woodwork before painting.

PRE-COMPLETION CHECK LIST FOR NEW HOUSES

IN THE ROOF SPACE

1. Brickwork or blockwork not made good around ends of purlins, binders etc. Brickwork or blockwork not made good up to roof line (especially party walls).
2. Torn or loose underlay requiring patching or refixing.
3. Roof insulation incomplete between joists or rafters.
4. Tank cover not provided.
5. Walk-boarding not provided.
6. Pipes and tanks not lagged where liable to freeze.

ALL ROOMS

1. Chipped or split window frames.
2. Damaged doors.
3. Incomplete skirting, chipped skirting.
4. Floor boards not made good around pipes.
5. Insufficient clips to heating pipes.
6. Damaged socket plates or light switches.
7. Missed coats of paint both on visible surface and under window boards etc.
8. Paintwork not touched up or untidily touched up
9. Missing floor tiles - especially around cupboards, fittings, doorways.
10. Paint splashes on doors or floors.
11. Loose balustrades and newels.

KITCHEN AND BATHROOM (INCLUDING AIRING CUPBOARD)

1. Insufficient clips to plumbing and heating pipes.
2. Damaged sanitary ware.
3. Loose bath panel.
4. Incomplete plaster making good around pipes (ceiling and walls).
5. Cracked or missing wall tiles.
6. Missing or loose plaster vents over airbricks.
7. Inadequately fixed kitchen fittings.

OUTSIDE OF HOUSE AND GARAGE

1. Missing, loose or broken roof tiles.
2. Loose or broken cladding tiles.
3. No chippings on flat roofs.
4. Missing lengths of gutter or drainpipe.
5. Broken gutter or drainpipe.
6. Missing wire balloon (soil and rainwater pipe).
7. Incomplete pointing.
8. Mortar splashes on brickwork.
9. No making good around waste pipes or to putlog holes.
10. Chipped or split window frames.
11. No mastic around frames and large gaps left.
12. Damaged cills or drip moulds.
13. Damaged doors.
14. Incomplete paintwork or top coat missed (especially at high level and on soffits and cills).

AROUND THE PROPERTY

1. Drives or paths not completed, incomplete making good around drains, gullies etc.
2. Manholes, gullies and stopcocks at wrong levels.
3. Missing gully grids and kerbs.
4. Loose manhole covers.
5. Soil banked around house.
6. Rubble not cleared from site.

Schedule 6

TOLERANCES FOR INITIAL BUILDING MOVEMENT

1. SHRINKAGE OF TONGUED MEMBERS, E.G. FLOOR BOARDS AND WINDOW BOARDS

When the shrinkage is so great that the tongue disengages, the builder should carry out remedial work such as re-laying the floor, or providing a cover mould to the frame edge of a window board. Decorations should be touched up. If there are gaps of $\frac{1}{4}$in. or over in general areas of flooring, irrespective of whether the tongue has disengaged, the builder shall take remedial action. Gaps smaller than $\frac{1}{4}$in. shall not be required to be remedied unless the tongue disengages. In the case of opening tongued and grooved joints or housings in staircases, the wedges shall be tightened or such other action taken as may be necessary to reduce movement and squeak to a normal level.

2. SHRINKAGE AND SWELLING OF DOORS OR WINDOWS WHERE THERE IS NO TWIST.

If a door or window swells to such an extent that more effort than a single firm push is required to open it, the builder shall carry out remedial work. If a door or window shrinks to such an extent that there is a gap of more than $\frac{1}{8}$in. between it and the frame or lining on any side, the builder shall take remedial action either by taking off and re-hanging more evenly to reduce a large gap on one side or by other appropriate action.

3. TWIST IN DOORS AND WINDOWS

When a door or window is warped or twisted to such an extent that it will not shut without effort or when shut is more than $\frac{1}{8}$in. out of alignment with the frame at any point, the builder shall take remedial action. Where the twist does not exceed $\frac{1}{4}$in., the door can normally be removed, butts and stops adjusted and the door re-hung. Where the twist is $\frac{1}{4}$in. or greater, replacement of the door or casement will normally be necessary.

4. TWIST OR SHRINKAGE LEADING TO DAMP PENETRATION

Where timber shrinks to such an extent that liquid water can enter the dwelling or joint, e.g. between two abutting frames, the builder shall take remedial action to prevent the ingress. This can be done by applying a cover mould or by any other appropriate means.

5. TIMBER/PLASTER GAP

Where, due to shrinkage, a gap appears between timber and plaster, e.g. between the frame and a plastered reveal or between wall plaster and a stair string, if the gap exceeds $\frac{1}{4}$in. the builder shall make it good and touch up decorations, but if it is less than $\frac{1}{4}$in., no action shall normally be required of the builder.

6. MOVEMENT OF TIMBER ON A PLASTER SURFACE

Where shrinkage occurs in a timber member moving over a plaster surface damaging decorations, e.g. a stair string behind which the wall is plastered, no remedial action shall be required.

7. CRACKS IN THE PLANE OF PLASTER SURFACES (WALLS)

Shrinkage or normal settlement cracks occuring in the plane of plaster surfaces shall be cut out, filled and decorations touched up, if they exceed 1/16in. in width. Cracks under 1/16in. are deemed to be hair cracks and capable of being made good in redecoration.

8. GAPS AT INTERSECTIONS IN PLASTERWORK

Shrinkage gaps at the wall/ceiling intersection should be filled in and decorations made good if the gap exceeds $\frac{1}{4}$in. The builder shall not be required to make good gaps less than $\frac{1}{4}$in. Gaps at vertical intersections such as in the angle between a partition and a wall shall be made good if they are larger than $\frac{1}{4}$in.

9. GAP BETWEEN BATH AND WALL TILING

Joist shrinkage and the weight of a filled bath may cause a gap to appear between the edge of the bath and splashback tiles. If this gap exceeds $\frac{1}{8}$in. the builder shall remedy it either by filling with a suitable mastic or by adjusting the bath legs or by any appropriate method.

10. CRACKS IN PLASTER CEILINGS

Hair cracks not exceeding 1/16in. in plasterboard/set ceilings normally following the line of joints in the plasterboard or elsewhere shall not be deemed to be defects. Cracks over 1/16in. shall be made good and decorations touched up.

11. LOOSE PLASTER

Loose plaster as opposed to cracks shall always be cut out and made good and decorations touched up.

12. LOOSE WALL TILES

Tiles which are actually falling off shall be replaced by the builder. Where tiling is loose and it is possible to insert a coin between the tiles and the plaster behind, remedial work shall be carried out.

13. GAPS AROUND PARTITIONS

Gaps can occur at the top, bottom or vertical intersections of partitions normally as a result of joist shrinkage. Where it is possible to see light through the gap, the builder shall make it good by means of a cover mould, plaster filling or other acceptable means.

14. SETTLEMENT CRACKS IN EXTERNAL BRICKWORK

Hair cracks not exceeding 1/16in. following the line of mortar joints shall not be regarded as defects. Cracks in mortar of over 1/16in. shall be cut out and made good. Where cracks appear in brickwork due to settlement, if the crack is deeper than $\frac{1}{4}$in., it shall be cut out and made good.

15. CRACKS IN EXTERNAL RENDERINGS

Cracks occuring in external renderings either in the plane, at intersections or at joints with other materials shall, if they exceed 1/16in, be cut out and made good. Unless there is evidence of, or risk of damp penetration, isolated cracks smaller than 1/16in. shall not be required to be made good. Crazing, i.e. a network of hair cracks shall be cut out and made good if there is any evidence of hollowness or risk of damp entry.

GUIDLINE FOR STANDARDS OF CONSTRUCTIONAL ACCURACY

FOR NEW HOUSES

Explanatory Note

Common inaccuracy defects are listed together with other items for which accuracy tolerances appear desirable. Against each is set any B.S.I. recommendation or any N.H.B.R.C. rule of thumb, as discussed in paragraphs 31-2 of the thesis. Comments are added.

Item	B.S.I. Proposal	N.H.B.R.C. Tolerance	Comment
Straightness of brickwork	$\frac{1}{2}$in. in 20ft.		Test B.S.I. for feasability
Verticality of brickwork	$\frac{3}{8}$in. in 10ft. subject to a maximum of $\frac{1}{2}$in. in any load-bearing wall.		Test B.S.I. for feasability
Straightness of brick block, or lightweight partitions.			Test measure sample houses
Verticality of partitions			Test measure sample houses
Horizontality of ridge line.			Test measure sample houses
Verticality of window and external door frames and margins of reveals.		$\frac{1}{8}$in. in 3ft.	Test N.H.B.R.C. for feasabilit

Item	B.S.I. Proposal	N.H.B.R.C. Tolerance	Comment
Tops and soffits of floor joists.	$\frac{3}{8}$in. under a 10ft. straight edge.	$\frac{1}{4}$in. in 3ft.	Test measure sample houses.
Floor levels			
Ceiling levels			
Floor to ceiling heights			Test measure for tolerance on Building Regulation requirements.
Headroom on stair bulkhead			Test measure for tolerance on Building Regulation requirements.
Bumpiness of floors			Devise a rolling test.
Waviness of ceilings			Devise a test.
Waviness of wall ceiling line			

Item	B.S.I. Proposal	N.H.B.R.C. Tolerance	Comment
Verticality of stair newel			Test measure sample houses
Horizontality of reveal soffits			Test measure sample houses
Horizontality of lining levels			Test measure sample houses
Verticality of lining joints			Test measure sample houses
Room diagonals			Test measure sample houses
Variation in margins around doors			Teast measure sample houses
Horizontality of lavatory basins			Test measure sample houses

APPENDIX B

DEFECT CLASSES

KEY

% of all defects

* less than 0.1%

Defect group

A	-	Accuracy
B	-	Broken/damaged
D	-	Damp penetration
F	-	Fixings/jointing
I	-	Incomplete work/missing items
M	-	Premature material breakdown
Me	-	Mechanical
N	-	Nuisance/health/safety
S	-	Building movement
St	-	Structural
U	-	Unclassified
W	-	General workmanship.

Seriousness group

I	-	Very serious (structural)
II	-	Very serious (other)
III	-	Less serious
IV	-	Non-serious
U	-	Unclassified

Responsibility

b	-	Bricklayer
c	-	Carpenter and joiner
d	-	Design
g	-	General trades
m	-	Materials
pd	-	Painter and decorator
pe	-	Plumber and engineer
pp	-	Plasterer and pavior
s	-	Site supervision
t	-	Roof tiler/layer
U	-	Unclassified

NOTE:

As the number of cases is 1028, the percentage of cases in which any defect class occurs is $\frac{\text{Number of occurrences}}{10}$

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
SUBSTRUCTURE					
Weeds through floor	2	*	M	II	s
Water on oversite	15	.3	D	II	d
Concrete - various	2	*	St	U	U
Blocked air brick	12	.2	M	II	s
Rubbish under floor	4	.1	M	III	c
Soft mortar	1	*	St	II	b
Sulphate attack	1	*	St	I	d
Brickwork - various	11	.2	St	U	U
Missing DP course	6	.1	D	I	b
Settlement/underpin	7	.1	St	I	d
Inadequate sleeper walls	4	.1	M	I	U
House out of plumb	1	*	A	IV	s
Floor settlement - consolidation	9	.2	St	I	s
Floor settlement - bearing/veg.	5	.1	St	I	d
Floor settlement - other causes	1	*	St	I	s
Retaining wall failure	1	*	St	I	d
Settlement cracks - walls	4	.1	St	II	U
Floor settlement - ducts	1	*	St	I	s
Mining subsidence	1	*	St	I	d
Missing DP membrane	8	.1	D	I	s
BRICKWORK AND BLOCKWORK					
Settlement cracks - M.g or observe	16	.3	S	II	s
Frost damage	1	*	M	II	s
Mortar too soft	5	.1	St	II	b

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Loose bricks	19	.4	F	III	b
Missing Lintol	1	*	St	I	s
Deflection of Lintol	6	.1	St	I	d
Bulging Wall	5	.1	St	I	d
Doorsteps - various	20	.4	U	U	U
Attached structures - breakaway	2	*	St	I	U
Rough brickwork	7	.1	W	IV	s
Blockwork - shrinkage cracks	23	.4	S	III	s
Concrete brick - shrinkage	1	*	S	III	s
Block shrinkage - plaster separation	2	*	S	III	s
Sound insulation	2	*	N	II	d
Cavity bridged	25	.5	D	II	b
Cavity bridged - foam filled	1	*	D	II	d
Damp entry - opening heads	22	.4	D	II	s
Damp entry - opening jambs	35	.7	D	II	s
Damp entry, walls various	15	.3	D	II	b
Defective bricks	19	.4	B	III	m
Incomplete pointing	23	.4	I	III	s
Rough pointing	23	.5	W	IV	b
Incomplete making good	29	.5	I	III	s
Rough pre-cast concrete	3	.1	W	IV	b
Incomplete work - roof space	20	.4	I	III	s
Wall cracked by fixing RWP etc.	4	.1	B	IV	t

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Mortar splashes	30	.6	B	IV	s
Missing airbrick	1	*	M	II	d
Provide airbrick condensation	1	*	M	II	d
Shrinkage cracks - brickwork	3	.1	S	III	U
Brickwork - various	13	.2	U	U	U

FIRST FIXINGS

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Defective/split roof timbers	4	.1	St	I	m
Inadequate purlins	3	.1	St	I	d
Trussed rafter defects	3	.1	St	I	s
Timber decay	2	*	M	I	m
Under size joists - general	1	*	St	I	d
Under size joists - trimmers	3	.1	St	I	d
Inadequate sundry bearers/ noggins	9	.2	I	III	c
Joist/partition shrinkage	25	.5	S	I	d
Joist shrinkage - general	3	.1	S	I	d
Uneven joists - fir out	2	*	A	III	c
Incomplete roof insulation	11	.2	I	III	s
Missing/loose gang boarding	7	.1	I	III	s
Roof deflection/out of line	2	*	A	IV	U
Dropped joist (packing)	4	.1	St	II	c
Joist cut away	6	.1	St	I	s
Roof trim/wall gap	23	.4	N	III	c
Loose roof trim	15	.3	F	III	c

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Roof trim various	29	.5	U	U	U
Loose cladding/panels	5	.1	F	III	c
Leaks cladding/panels	14	.3	D	II	d
Cladding and panels - various	4	.1	U	U	U
Various	6	.1	U	U	U
ROOF COVERINGS					
Torn/loose underlay	34	.6	D	III	s
Underlay not reaching gutter	9	.2	D	III	t
Tiles not interlocking	7	.1	F	III	t
Broken tiles	37	.7	B	II	s
Loose/missing tiles	22	.4	F	III	s
Cracked/missing cement work	29	.5	F	III	t
Roof leak - chimneys	42	.8	D	II	t
Roof leak - pipes & flues	21	.4	D	II	t
Roof leak around dormer	19	.4	D	II	t
Roof leak upstands	15	.3	D	II	t
Roof leak - roof lights	1	*	D	II	t
Roof leak - various	22	.4	D	II	t
Ponding/leaks to flat roofs	23	.4	D	II	d
Edge overflow from small flats	10	.2	D	III	d
Blistery/loose felt	3	.1	D	III	t
Chippings omitted	1	*	I	III	t
Roof leak - aluminium	2	*	D	II	t
Roof leak - asphalt	1	*	D	II	t

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Roof leak - synthetic rubber	1	*	D	II	t
Loose vertical tiles	27	.5	F	II	s
Damp entry - vertical tiles	6	.1	D	II	t
Various	9	.2	U	U	U
RAINWATER DISPOSAL					
Leaks at gutter joints	36	.7	F	II	t
Non-alignment/overflow of gutters	34	.6	F	II	t
Loose RWP	10	.2	F	III	t
Broken/loose/sagging gutter	7	.1	F	II	U
Broken RWP	6	.1	B	II	s
Undersize/incomplete RWP	6	.1	N	II	s
Wire balloons missing	3	.1	I	III	s
Blocked RWP	2	*	N	II	t
Insufficient RWP's and drainage	6	.1	N	II	d
Missing gutter	1	*	N	II	s
CHIMNEYS AND FLUES					
Smoke - raise stack	9	.2	N	II	d
Smoke - provide cowl	7	.1	N	II	d
Smoke - alter throat/ lintol	13	.2	N	II	b
Smoke - blockage	10	.2	N	II	s
Smoke - unspecified	8	.1	N	II	U
Lining missing/defective	14	.3	N	II	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Stoves and firebricks - various	16	.3	Me	II	b
Tiled surrounds - minor	20	.4	B	IV	U
Hearth construction	1	*	N	II	b
Various	20	.4	U	U	U
WINDOWS					
No opening lights	4	.1	N	II	d
Missing mastic	63	1.2	I	II	s
Chipped/split frame/ window board	27	.5	B	IV	s
Out of plumb/sill ponding	8	.1	M	III	b
Faulty/missing drip moulds	11	.2	M	II	s
Sill projections and checks	8	.1	M	II	m
Faulty 2-piece sill	2	*	M	II	m
Wet rot and black fungus	4	.1	M	II	m
Replace sashes	11	.2	B	III	U
Twist/swell/ease	42	.8	S	III	s
Loose/shrunk sashes/stops	11	.2	S	III	s
Adjust ironmongery	22	.4	S	III	U
Broken ironmongery	24	.4	B	III	m
Shrinkage - frame/plaster	10	.2	S	III	d
Shrinkage - frame/window board	35	.7	S	III	d
Twisted/split window board	25	.5	S	III	s
Damp entry - glazing/ around sashes	27	.5	D	II	c
Pivot windows (various)	7	.1	Me	U	m
Metal windows (various)	4	.1	U	U	m

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Sliding windows (various)	1	*	Me	U	m
Louvre windows (various)	1	*	Me	U	m

EXTERNAL DOORS AND FRAMES

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Loose frames	27	.5	F	III	c
Missing mastic	24	.4	I	II	s
Out of plumb	4	.1	A	IV	U
Provide weather bar	10	.2	D	II	d
Inadequate/ill-fitting bar/board	23	.4	D	II	c
Provide weather board	25	.5	D	II	d
Provide weather strip	16	.3	D	II	d
Damp entry around door	29	.5	D	II	c
Damp entry - panels	4	.1	D	II	m
Damp entry - glazing	7	.1	D	II	c
Thresholds - checks and falls	9	.2	M	II	m
Wet rot	7	.1	M	II	m
Damage by builder	23	.4	B	III	s
Shrunk/loose fitted doors	16	.3	S	III	s
Warped - replace	26	.5	S	III	m
Warped - adjust	30	.6	S	III	s
Ease and adjust	49	.9	S	III	s
Open tenon joints	3	.1	S	III	m
Adjust ironmongery	22	.4	S	III	m
Loose ironmongery	4	.1	F	III	m
Broken/corroded ironmongery	11	.2	B	III	m
Various	18	.3	U	U	U

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
INTERNAL DOORS AND LININGS					
Loose lining	20	.4	F	III	c
Lining out of plumb	8	.1	A	IV	c
Warped/split lining	20	.4	S	III	s
Loose stop	5	.1	F	III	c
Architraves missing	14	.3	I	III	s
Wet rot	1	*	M	II	m
Door cut short	8	.1	N	III	s
Damaged by builder - m.g. /renew	24	.4	B	III	s
Inefficient sliding door	15	.3	Me	III	c
Loose ironmongery	20	.4	F	III	c
K,B, & AC - ill fitting doors	36	.7	S	III	c
Ill fitting doors - living	51	.9	S	III	c
Ill fitting doors - unspecified	44	.8	S	III	s
Loose fitting doors	27	.5	S	III	s
Shrinkage to screens	1	*	S	III	U
Adjust ironmongery	27	.5	S	III	U
Shrinkage - various	4	.1	S	III	U
Various	8	.1	U	U	U
FLOOR BOARDS AND SKIRTINGS					
Insufficient/projecting nails	3	.1	F	II	c
Doorways - ridges/missing bearers	3	.1	F	II	c
Incomplete mg	29	.5	I	III	s
Loose boards	29	.5	F	III	c

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Board shrinkage	22	.4	S	III	s
Spring, squeak, creak	18	.3	S	III	c
Damaged/split skirting	15	.3	B	III	s
Loose skirting	23	.4	F	III	c
Skirting/wall gap	1	*	F	III	c
Skirting/floor shrinkage gap	33	.6	S	III	d
Wet rot in skirting	1	*	M	II	m
Board cupping	4	.1	S	III	s
STAIRCASES					
Width of winders	1	*	A	II	d
Defective string joints	5	.1	F	II	m
Squeak, creak, loose treads and risers	33	.6	S	III	s
Loose balustrades and newels	23	.4	F	II	s
String/wall shrinkage	31	.6	S	III	d
Spandrel/apron shrinkage	2	*	S	III	m
Insect attack/wet rot	2	*	M	II	m
Newel out of plumb	8	.1	A	IV	c
Various	20	.4	U	U	U
Unsafe balustrade design	3	.1	N	II	d
OTHER JOINERY					
Kitchen units - doors	15	.3	U	IV	U
Kitchen units - worktops and others	44	.8	U	IV	U
Kitchen units - fixings	7	.1	F	IV	s
Pipe casings incomplete/shrinkage	11	.2	S	III	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Meter cupboard incomplete/warped	5	.1	U	III	s
Trap doors - ill fitting	6	.1	W	III	U
Hardwood mantles loose/ bowed	8	.1	S	III	U
Hardwood features - various	4	.1	U	U	U
Serving hatches	7	.1	U	U	U
Various	12	.2	U	U	U
INTERNAL PLUMBING					
Loose pipes/water hammer	36	.7	F	II	s
Back fall	12	.2	N	II	pe
Self siphonage	6	.1	N	II	d
Soil or waste blockage	2	*	N	II	pe
Ticking soil pipe	5	.1	N	IV	pe
Missing wire balloon (soil)	33	.6	I	II	s
Loose basin	31	.6	F	III	pe
Other loose fittings	14	.3	F	III	pe
Ill positioned WC seat	23	.4	F	III	s
Inefficient taps or ball valves	11	.2	Me	II	m
Inefficient WWP and siphonic pans	2	*	Me	II	m
Inefficient combination tank	4	.1	Me	II	m
Inefficient shower	4	.1	Me	II	m
Cracked basin	3	.1	B	II	s
Cracked WC/WWP	4	.1	B	II	s
Chipped/shattered bath/ shower	10	.2	B	II	s
Chipped sink top	5	.1	B	II	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Defective overflow	3	.1	U	III	U
Leak and CD - WC/SV pipe	25	.5	F	II	pe
Leak and CD - flush pipe	4	.1	F	II	pe
Leak and CD - sink waste/trap	16	.3	F	II	pe
Leak and CD - towel rail	2	*	F	II	pe
Leak and CD - cylinder joint	4	.1	F	II	pe
Leak and CD - pipe work/general	34	.6	F	II	pe
Defective cylinder	8	.1	Me	II	m
Boiling/rust	4	.1	Me	II	d
Rusty/damaged taps	12	.2	B	IV	m
Inadequate lagging pipes/ducts/tanks	28	.5	I	III	s
Missing tank covers	9	.2	I	III	s
Loose bath panel	17	.3	I	III	s
Shrinkage gap - bath tiling	53	1.0	S	III	d
Various	15	.3	U	U	U

ENGINEERING SERVICES

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Heating under-performance	15	.3	U	II	d
Replace boiler	4	.1	Me	II	m
Pumps, switches, valves thermostats	45	.8	Me	II	m
Faulty/leaking radiator valves	10	.2	Me	II	m
Water in u/floor duct	2	*	D	II	d
Faulty grilles, vents, trunking	13	.2	N	II	m
Leaks - pipe, radiator, boiler	43	.8	F	II	pe

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Oil leaks	2	*	F	II	pe
Loose radiators	12	.2	F	II	pe
Loose pipes/water hammer	19	.4	F	II	pe
Rust in water	1	*	Me	III	d
Gas faults and carbon monoxide	11	.2	N	II	s
Wiring faults - heating system	3	.1	Me	II	U
Faulty radiators	8	.1	Me	II	m
Faulty immersion heaters	9	.2	Me	II	m
Broken electrical accessories	18	.3	B	II	s
Faulty switches	11	.2	Me	II	m
Loose/ill-sited cables	8	.1	F	II	pe
Faulty extract fan	1	*	Me	II	m
No heating to airing cupboard	1	*	N	III	d
Electrical faults (various)	14	.3	Me	II	U
Various	12	.2	U	U	U
Incomplete builders work	27	.5	I	U	s
PLASTERING AND WALL TILING					
Loose external rendering	13	.2	S	II	pp
Cracked external rendering	18	.3	S	II	pp
External rendering (various)	16	.3	S	U	U
Missing plaster vents	6	.1	I	III	s
Uneven ceilings	22	.4	A	IV	s
Various	7	.1	U	U	U
Joints in ceiling and thin cover	20	.4	W	III	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Cracking cornice	2	*	S	III	s
Crack - ceiling or soffit	21	.4	S	III	s
Crack - wall/ceiling	31	.6	S	III	s
Crack - above opening	21	.4	S	III	s
Crack - reveals, beside, below opening	28	.5	S	III	s
Crack - wall/partition	6	.1	S	III	s
Crack - by rads/pipes	5	.1	S	III	s
Crack - settlement	6	.1	S	III	s
Crack - walls and unspecified	48	.9	S	III	s
Loose/flaking ceiling	8	.1	S	III	pp
Loose/flaking around opening	41	.8	S	III	pp
Loose/flaking (unspecified)	46	.9	S	III	pp
Loose plasterboards	12	.2	F	III	pp
Incomplete m.g. pipes etc.	48	.9	I	III	s
Rough/uneven areas	42	.8	W	IV	s
Blown areas	5	.1	M	II	m
Efflore sence and lime blows	13	.2	M	II	m
Nôn-adherence, bulge, loose areas	19	.4	M	II	m
Nail blows	5	.1	M	II	m
Inadequate cover to cables	2	*	W	III	pp
Loose wall tiling	45	.8	S	III	pp
Loose grout	11	.2	S	III	pp
Cracked tiles	11	.2	B	III	s
Loose tiles/plaster shrinkage	1	*	S	III	U
Untidy making good	8	.1	W	IV	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Shrinkage - tiles/ architraves	4	.1	S	III	s
Tile sills (various)	8	.1	U	U	U
FLOOR FINISHES					
Hollow/broken/soft screed	16	.3	M	II	pp
Dirty screed	7	.1	W	III	pp
Screed out of level	14	.3	A	IV	s
Loose/cracked tiles	45	.8	F	II	pp
Missing tiles	8	.1	I	III	s
Stained, efloresent, rough	12	.2	B	IV	s
Swelling/shrinking block/strip	22	.4	S	III	s
Inadequate fixing for chipboard	11	.2	F	II	c
Rough or badly polished block or strip	6	.1	W	IV	s
Broken/uneven floor in openings	14	.3	N	II	s
Various (including porches and stairs)	16	.3	U	U	U
GLAZING AND EXTERNAL PAINTWORK					
Blemished glass	19	.4	B	IV	m
Loose/cracked/putties	43	.8	F	III	pd
Incomplete work and missed coats	65	1.2	I	IV	s
Paint breakdown - sills	31	.6	M	III	pd
Paint breakdown - cladding	12	.2	M	III	pd
Paint breakdown - other and unspecified	46	.9	M	III	pd
Rough paintwork	13	.2	W	IV	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Rust staining	9	.2	B	IV	pd
Oiling/polishing various	8	.1	U	U	U
Splashes and blemishes	8	.1	B	IV	s
Colour wash, coating, metal, etc.	5	.1	U	IV	U
INTERNAL DECORATION					
Incomplete work and missed coats	56	1.0	I	IV	s
Rough work/paint breakdown	67	1.2	W	IV	s
Flaking walls/ceiling	14	.3	M	IV	pd
Rough walls/ceiling	17	.3	W	IV	pd
Rust staining	11	.2	B	IV	pd
Untidy/incomplete touching up	1	*	I	IV	s
Seal/polish various	22	.4	U	U	U
Rough papering	8	.1	W	IV	s
Stains and splashes	16	.3	B	IV	s
GARAGES					
Inadequate turning space	1	*	N	U	d
Foundations	6	.1	St	U	U
Slab construction	11	.2	St	U	U
Slab levels, falls, drain off	16	.3	A	U	U
Brick/block work and rendering	50	.9	U	U	U
Roof structure and coverings	48	.9	U	U	U
RW disposal	19	.4	U	U	U
Up and over doors	19	.4	U	U	U

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Joinery	59	1.1	U	U	U
Services and finishes	38	.7	U	U	U
DRIVES AND PATHS					
Unsuitable gradient/no steps	13	.2	A	II	d
Missing/incomplete work	26	.5	I	III	s
Settlement	35	.6	St	II	s
Concrete deterioration	29	.5	M	II	g
Tarmac deterioration	22	.4	M	II	g
Ponding/falls/levels	53	.9	A	II	s
Splashes and stains	4	.1	B	IV	s
Above DPC	3	.1	D	II	s
Unsuitable materials	1	*	M	II	U
Various	10	.2	U	U	U
DRAINAGE					
Manholes - levels/loose/cracked	20	.3	U	II	s
Gully levels, curbs, loose, grids	29	.5	U	III	s
Defective joint to RWP	10	.2	F	II	g
Falls - relay	4	.1	A	II	d
Inappropriate route	1	*	N	II	d
Blocked pipe/gully	15	.3	N	II	g
Leaks and CD (including joint to soil)	6	.1	F	II	g
Inadequate surface water drains	24	.4	N	II	d
Inadequate drive drains	13	.2	N	II	d
Trench settlement	4	.1	St	II	s

Defect class	Occurrences	% of all defects	Defect group	Seriousness group	Responsibility
Broken pipes	1	*	B	II	g
OTHER EXTERNAL WORKS					
Retaining wall not provided	10	.2	St	I	d
Retaining wall structural failure	5	.1	St	I	d
Boundary wall - footings, sinks, slips	8	.1	St	I	s
Boundary walls - frost, mortar	10	.2	M	II	s
Boundary walls - various	7	.1	U	U	U
Water supply (box, levels, burst)	6	.1	U	II	s
Depth of electrical and water mains	3	.1	N	II	s
Failure to grade, soil levels	10	.2	I	III	s
Rubbish not cleared	11	.2	I	III	s
Banking of earth next to walls	3	.1	D	II	s
Various	14	.3	U	U	U

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