TOWARDS PEST FREE DWELLINGS IN THE URBAN ENVIRONMENT

R. G. MURPHY and S. TODD
Department of Environmental Health and Housing, University of Salford, UK

Abstract—Pests are attracted to buildings for shelter, food and harbourage. They will take advantage of many different types of hiding places, from tiny crevices to large hollow spaces. The benefits of these hiding places to pests are two fold. Firstly concealment can allow quite large populations to develop unnoticed and render them difficult to find. Secondly the protection provided by such features can prevent or at least reduce the effectiveness of extermination procedures and/or pesticides. Consequently, infestations are more likely to occur and persist in buildings with ample harbourage (for example spaces behind the skirting boards, suspended ceilings, hollow partitions, ducts and conduits) than in those providing little or no shelter. The infestations resulting from such invasions into the domestic environment, in addition to causing economic loss, by, for example compromising the fabric of the dwelling, can result in anxiety and distress to residents. This paper examines the characteristics which facilitate the build up of infestations. Features such as gaps in the construction facilitate pest invasion, but in many cases can be remedied by ensuring good building practice. Avoidance of certain design features such as district heating and common service ducts and the adoption of specific measures where the risk of infestation may be high can reduce the likelihood of infestation. Building elements, such as prefabricated stud partitions and hollow cored doors which provide suitable harbourage for pests may be eliminated by using alternative materials. Prior to the building of new dwellings a programme will be developed to demonstrate the logic and sequence of events and project resources required during construction. This paper utilises a standard building sequence to highlight the features and elements of the construction process which may facilitate the possibility of infestation in the future. In addition to highlighting potential problems and solutions, suggestions are made for alternative materials and elements which may reduce the risk of invasion and infestation.

INTRODUCTION

Insects constitute one of the most important groups found infesting dwellings and apart from the obvious ways in which they may cause damage through economic loss (e.g. by eating or contaminating foodstuffs) their activities and habits can often be responsible for considerably more harm. They can affect the structural performance of the building and reports of their disease carrying potential are well documented (Cloarec *et al.*, 1992; Fotedar *et al.*, 1991; Hickin, 1985; Busvine, 1980; Service, 1986; Burgess, 1990). They may also cause anxiety and distress amongst residents resulting in a high proportion of voided properties.

Dwellings will be attractive to insects in providing shelter, food and harbourage. Access to domestic properties may be achieved via a myriad of routes and some invasions will inevitably be accidental and will not lead to insidious infestations. It is neither practical nor necessary to guard against such accidental entry and this paper intends to explore the building defects which may arise during construction enabling pest populations to gain and maintain access within dwellings. Most building defects are avoidable and in general occur, not through a lack of knowledge, but by non-application or mis-application of it (Ransom, 1987). Where appropriate this paper discusses the defects which may facilitate infestations and discusses the methods of preventing or reducing levels of infestations. Although this paper deals with the threat from insect pests it is important to acknowledge the role that other pest groups may play in insect invasion. Damage as a result of rodent activity may well open up new routes of entry for insect pests and many insect infestations have been traced to bird nests within the roof void. It is therefore often necessary to ensure the exclusion of these groups to inhibit ingress of insect pests.

The definition of adequate or inadequate housing design may be interpreted in different ways. Although the building may perform adequately in terms of its functional requirements and satisfy those involved in the building process, inadequacies may arise in public health terms by allowing the establishment of chronic infestations (Schofield *et al.* 1990). The risk of infestations can be greatly reduced by good house design, good building practice during construction and the use of appropriate materials. Overwhelming problems are faced by some local authorities and pest control companies in trying to control and contain pest infestations in the domestic environment. This could be due to designers and builders ignoring the possibility of future infestations or merely

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concentrating on insects which could threaten the structural integrity and function of the building (Schofield and White, 1984). The potential threats to health are generally overlooked during design and construction and the remedial actions required to disinfest the dwelling are often hampered by poor design and bad practice. Many constraints are placed on constructing low cost housing which is easy to build, is comfortable and acceptable to householders and uses appropriate materials (Schofield and White, 1984). The materials and methods employed in the construction process may have appeared economically prudent at that stage, but the cost of undertaking control programmes for persistent infestations have far exceeded this saving.

Whilst the eradication of existing infestations is important, there are obvious advantages in preventing or minimising their occurrence by denying the pests access (Lea, 1980). Several studies have identified common design features which increase the likelihood of infestation and assist its longevity (Beasley *et al.*, 1988; Runstom and Bennett, 1984;) District heating systems and common service connections have aided in the dissemination of infestations to other dwellings. It is acknowledged that poor hygiene may encourage infestations, however proper design and construction should prevent subsequent spread to other buildings or areas of the complex and make it easier to treat and eradicate the infestation efficiently.

Once they have gained access, insects will exploit numerous types of hiding place, from tiny crevices to large hollow spaces. These sites, in addition to allowing quite large infestations to develop unnoticed can also afford them protection by reducing the effectiveness of extermination and cleansing programmes (Busvine, 1980). Consequently, infestations are more likely to occur and persist in buildings with ample harbourage (for example spaces behind skirting boards, suspended ceilings, hollow partitions, ducts and conduits), than in those providing little or no shelter (Owens and Bennett, 1982; Berthold and Wilson, 1967; Runstrom and Bennett, 1984; Barcay *et al.* 1990).

Dampness in new build can often be traced to poor building practice (Addleson, 1992). Dampness may affect a building in several ways, for example, rising, penetrating, condensation, leaking services etc. In addition to these problems which may affect the structural integrity of the building it may also create an ideal atmosphere for insects which thrive in warm, damp environments. Faulty foundation design and poor ground conditions can also lead to cracking in the external walls of buildings, leading to penetrating dampness and the possibility of pest ingress (Building Research Establishment, 1982). Careful checking of design and construction should help to curtail some of these problems. Dampness may lead to attack by fungi from for example dry and wet rot (*Serpula lacrymans* and *Coniophora puteana*) and attack by beetles and other wood borers. The combined nature of the attack by wood boring beetles and fungal decay often leads to much earlier structural failure or weakening than would be the case if only one agent of decay were present and the importance of these insects in undermining the structural stability of the building should not be overlooked (Coggins, 1980).

METHODS

A standard building sequence can be employed in identifying those stages in the construction process which may contribute to later infestations. A building sequence or network for a typical two-storey dwelling is presented in Figure 1. It illustrates the logic and sequence of events that constitute the construction of a new dwelling and the dependency of events to others. No event can be reached in a project before the activity which immediately precedes it is completed. For example the brickwork to damp proof course (dpc) cannot be built before the concrete has been poured in the foundations.

The building sequence will be split into 4 stages as shown in Figure 2 and the potential pest risks highlighted for each stage. The four main stages are:

1. **Substructure which includes all work below ground level;**
2. **Superstructure, which includes work to the shell of the dwelling above ground**
3. **Internal work including finishes and**
4. **External works including fences and paths.**

The full building sequence has been included for completeness, but not every activity will have implications for future infestations. Many building defects could be avoided or at least the worst of their effects reduced considerably by careful attention to design and workmanship.

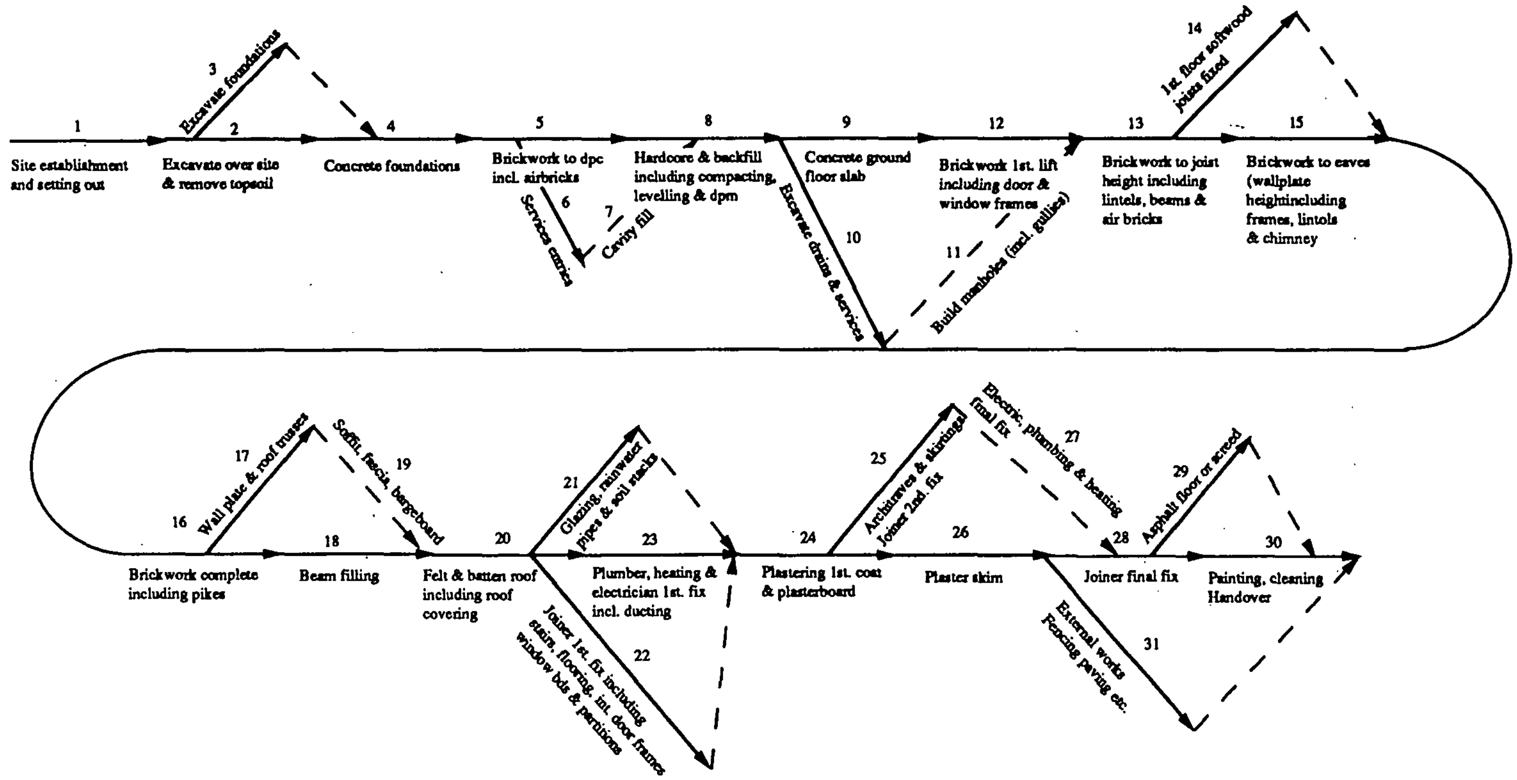

Figure 1. A typical network showing a building sequence for a two-storey dwelling

Building Sequence

Site Establishment and Substructure		
	1.	Site establishment and setting out
	2.	Excavate over site and remove topsoil
	3.	Excavate foundations
	4.	Concrete foundations
STAGE 1	5.	Brickwork to damp proof course (includes air bricks)
	6.	Services entry
	7.	Cavity fill
	8.	Hardcore and backfill (including compacting, levelling & damp proof membrane (dpm)
	9.	Concrete ground floor slab
	10.	Excavate drains and services
	11.	Build manholes (includes gullies)
Superstructure		
	12.	Brickwork 1st. lift (including door and window frames)
	13.	Brickwork to joist height (including lintels, beams & air bricks)
	14.	1st. Floor softwood joists fixed
	15.	Brickwork to eaves (including chimney)
STAGE 2	16.	Brickwork complete including pikes
	17.	Wall plate and roof trusses
	18.	Beam filling
	19.	Soffit, fascia & bargeboard
	20.	Felt and batten roof (including roof covering)
	21.	Glazing, rainwater pipes & soil stack
Internal work		
	22.	Joiner first fix including stairs, flooring, internal door frames, window boards & partitions
	23.	Plumber, heating & electrician first fix (includes ducting)
	24.	Plastering first coat & plasterboard
	25.	Architraves & skirtings. Joiner second fix
STAGE 3	26.	Plaster skim
	27.	Electrician, plumber & heating final fix
	28.	Joiner final fix
	29.	Asphalt floor or screed
	30.	Painting, cleaning, handover
External Works		
STAGE 4	31.	External works. Fencing, paving etc.

Figure 2: The building sequence split into four stages

SITE ESTABLISHMENT AND SUBSTRUCTURE

The work below ground is undertaken during site establishment and substructure. The range of activities will include foundations, services and service entry (for example drainage), brickwork to damp proof course and construction of the ground floor.

Site establishment and setting out

Good hygiene during the construction process must be enforced to prevent the creation of insect harbourages which would facilitate their survival until more suitable accommodation was completed. Disused drains and sewers could provide easy access to domestic premises and the activity of rats could exacerbate this problem. As a result all live drains should be sealed during construction when not in use and disused drains should be grubbed out and cement grouted (Lea, 1980; Hall and Griggs, 1990).

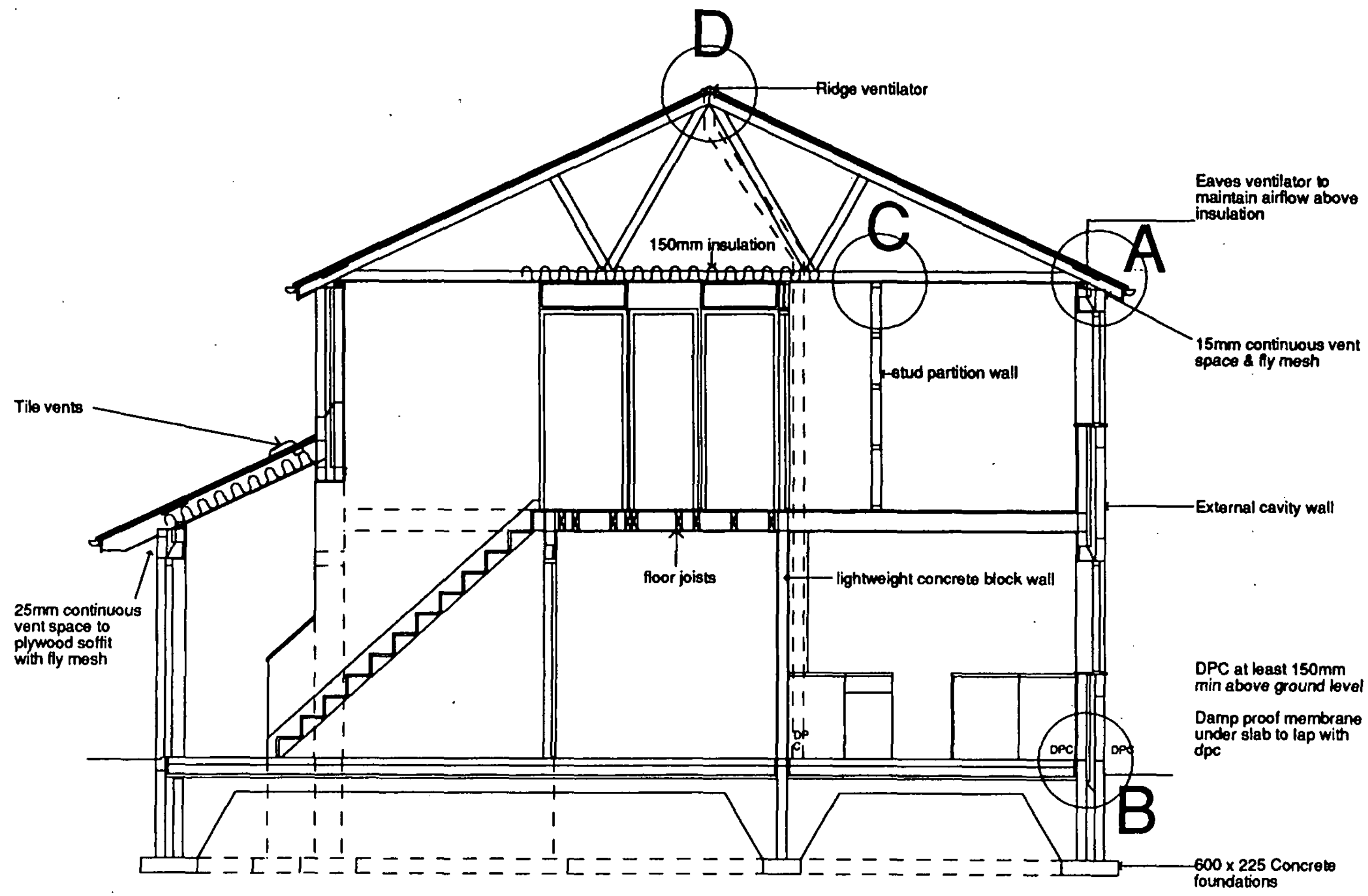

Figure 3. Typical section through a two-storey dwelling

Excavate foundations

Foundations should be designed according to the load bearing capacity of the ground and the appropriate guidance (for British guidance refer to Approved Document A1/2 of the Building Regulations and BS 8004: 1986). Defective foundations will affect the support, causing settlement and soil movements. Differential settlement is serious as the increased stresses applied to certain parts of the building may cause cracking and structural failure. This cracking may lead to the establishment of easy routes of insect access into the domestic environment (Figure 3).

Brickwork to damp proof course

Airbricks are specially designed bricks or grilles which form part of the external wall to a dwelling (Cornwell, 1979). They ventilate the subfloor space, reducing the moisture content of air and decreasing the likelihood of the timbers rotting in a suspended timber floor. In buildings with gas central heating airbricks also prevent the build up of gas in the sub floor space. They should be cased from the external through to the internal wall to prevent excessive heat loss and this measure also denies incoming insects access to the cavity between the walls. Airbricks are inserted below the damp proof course at approximately two metre centres (Figure 3).

British Standard 493 specifies suitable materials for airbricks (clay, concrete, cast iron or unplasticised PVC) and a maximum hole dimension of 9.5mm. However this would not prevent the entry of most insects and it may be necessary to insert an insect proof screen manufactured from corrosion resistant materials to the back face of the airbrick. According to the British Standard, suitable screen materials are perforated zinc with a safe hole pattern of thickness 0.5 mm or copper mesh of 0.4 mm thickness. As a result of mechanical damage insect ingress via airbricks can also occur and therefore an adequate maintenance policy needs to be implemented to deny this route of entry.

Hardcore and backfill

Following completion of the brickwork to dpc level a layer of stone, known as hardcore is placed (see Figure 4) which will support the ground floor slab. Hardcore should compact easily (to ensure structural stability) and where the depth is greater than 600mm the National House Building Council recommends that an alternative floor design (for example suspended slab) be used. It is also important to ensure that vegetable matter is not a constituent of hardcore as it may provide a food source for pests and will decay, thus causing structural problems (Building Regulations 1991, Approved Document C4). Wood should also be avoided as there is a potential for introducing dry rot fungus.

Concrete ground floor slab

If a solid ground floor slab is used it is essential that the gap between the external walls and slab be completely filled. Any gaps arising due to shrinkage of concrete or poor workmanship should be grouted to prevent ingress of pests.

Build manholes (including gullies)

Entry of insects via the drainage system is extremely unlikely as modern systems have water seals incorporated. However gullies may present a potential risk if they are not properly maintained. Build up of moist debris around the gully trap can provide sufficient food for hundreds of insects including flies and should be cleaned regularly using disinfectants.

SUPERSTRUCTURE

The main shell of the dwelling above ground is known as the superstructure and includes external walls, first floor joists, roof construction, rainwater pipes and soil stacks etc. Many defects can be introduced at this stage as a result of poor workmanship. Pest access may be facilitated by poor filling of the mortar joints in the external wall and this can also have implications for insulation and weather exclusion of the building.

Brickwork to 1st lift

Gaps around window and door frames should be sealed with suitable sealants such as mastic to provide an effective barrier to both the elements and pests. In areas of very high risk the only solution available in excluding flying insects may be the introduction of fly screns. However although this may be acceptable in industrial food premises, they would not normally be encountered in the domestic situation. It is common practice in new windows to use 'hit and miss' ventilators within the frame. Specifications for these ventilators should include fly screens (BS 5250).

Brickwork to joist height

Airbricks which ventilate kitchens, bathrooms, larders etc. may appear higher up the external wall and the recommendations outlined earlier apply. If insects gain access to the cavity between the external and internal walls they may enter the interior via first floor joists which have not been properly placed. These joists must be tightly fitted into the internal leaf or alternatively, joist hangers (a metal shoe fixed onto the end of a joist) may be used (Figure 3).

Brickwork to eaves

Many pest groups are attracted to the roof space as it provides a dark undisturbed harbourage and there are often nesting materials available. Additionally it provides a primary site for insect attack of timber (e.g. furniture beetle) (Cornwell, 1979). Timber damage resulting from wood-boring beetle activity is often initiated in the roof void and can have dire consequences for the structural integrity of the dwelling. This problem has been addressed in the Building Regulations which state that in specified area in the south of England all softwood roof timbers, including ceiling joists should be treated with a suitable preservative against the house longhorn beetle (*Hylotrupes bajulus*). Insects may gain entry to the roof space either actively or passively. Bird nests are often a rich source of insect fauna and these insects can invade other parts of the dwelling. Insects may also enter the roof void via the eaves. Both of these sources of potential infestation may be controlled by restricting the voids at eaves level (Figure 3). These gaps cannot be completely sealed as ventilation is required to limit condensation problems but it is common practice to use a plastic ventilation strip with a nominal mesh size of 4 mm in accordance with the recommendations found in BS 5250 and these would not restrict air flow.

Although pantiles may provide an aesthetically pleasing finish to the roof, there are potential problems in their use. Their humped shape can create harbourage underneath the tile and facilitate entry into the roof space. Comb fillers may be used to close up these gaps but checks must be carried out to ensure no large gaps remain under the pantiles. The roof space must be ventilated and the tile and ridge ventilators (see figure 3 (location D)) should have integral screens to prevent insect entry. Flashings around the chimney stack should be checked to make sure there are no large gaps present which would facilitate insect entry to the roof space.

INTERNAL WORKS

Internal works will encompass such activities as the fixing of staircases, flooring and internal door frames and doors, completion of plumbing and electrical work, plastering, floor screed and painting.

Joiner first fix

The internal divisions within a dwelling may be solid or timber framed walls (see Figure 3 (and location C)). Solid walls are usually constructed of block work whilst timber frame walls are a

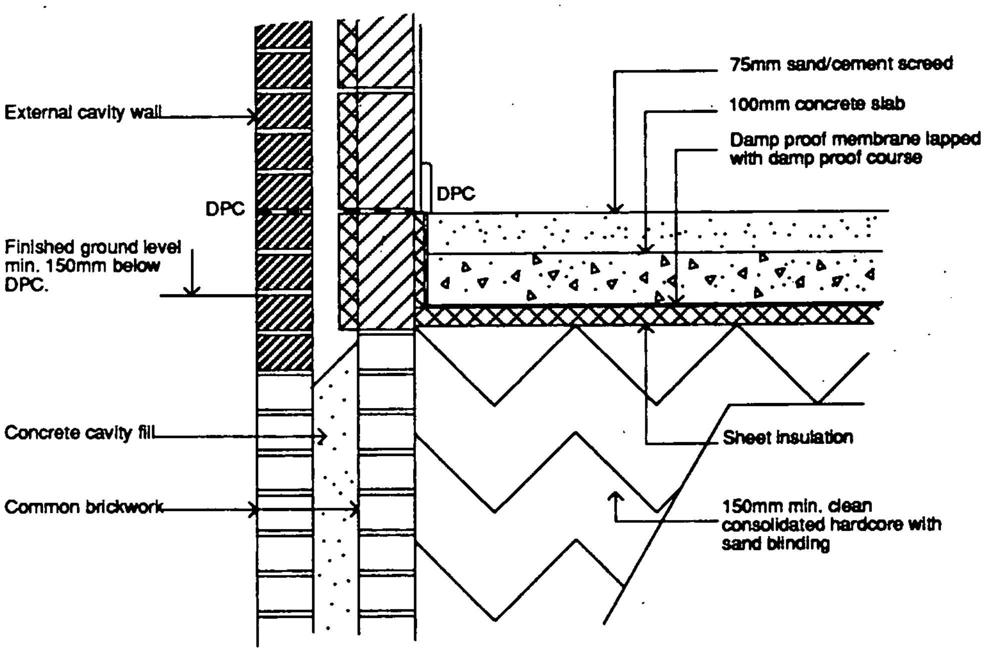

Figure 4. Detail of ground floor slab with external wall at B

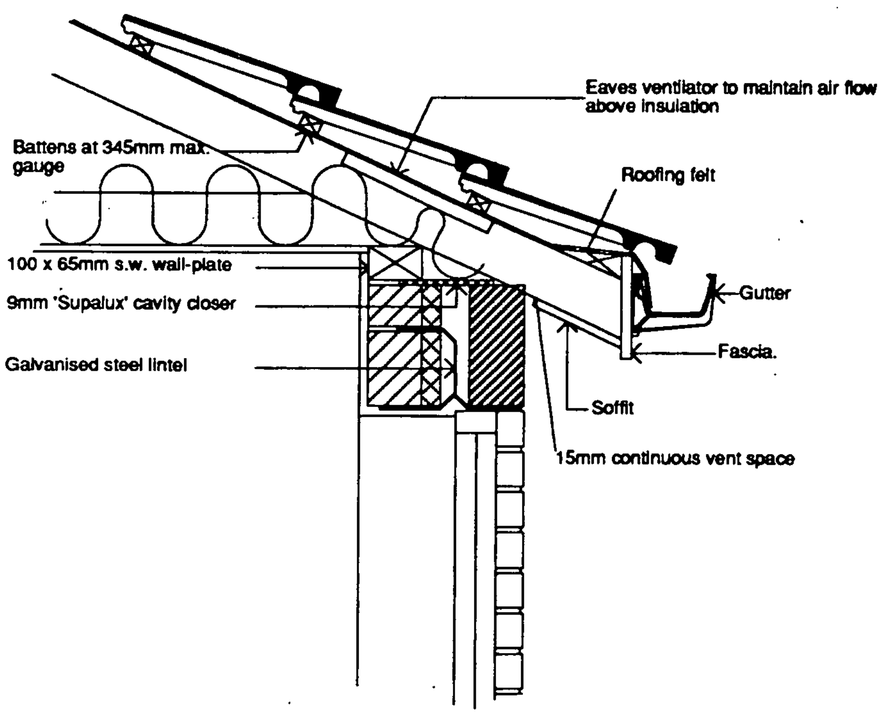

Figure 5. Eaves detail at A

framework of timber finished with plasterboard and skim. A modern trend is to finish solid block walls using a dry lining technique, where a layer of plasterboard is stuck onto the wall with plaster dabs. This leaves a 5 mm gap between the plasterboard and the block work and could provide a potential harbourage for insects and this situation would be almost impossible to treat in extermination programmes. In the past, walls have been constructed from fibre or particle boards. The latter provides cavities suitable for pest harbourage and on occasions partitions have been so thin as to allow pests to migrate between properties. Ideally, solid walls with a traditional two coat plaster work are preferable. Where this is not feasible, factory produced partition systems should be avoided as they provide a distribution network for pests to disperse throughout the structure. A framework of timber with vertical studs which are properly sealed at the top and bottom with head and sole plates afford an acceptable alternative. Again, these must be finished with plasterboard and skim which should be continuous, sealing all gaps at floor and ceiling level and excluding insect pests from these potential harbourages.

Severe cracking of the internal plaster as a result of foundation movements and minor cracking as a result of plaster shrinkage may furnish insects with suitable harbourage sites. Studies have been undertaken (Farmer and Robinson, 1984) to assess the effectiveness of caulking cracks to limit harbourage. However, the results revealed that the value of such a programme was limited as there was no significant difference in cockroach control between caulked and uncaulked premises. Caulking may be useful as an element of a control programme where sanitation and improved construction are also incorporated. Major cracking of plaster as a result of foundation movement will obviously be avoided if the foundation work is carefully controlled and good building practice is adopted during the substructure stage.

Plumber, heating and electrician first fix

Chases for wiring etc. must be sealed at wall-floor and wall-ceiling junctions to prevent harbourage and deny entry points to the insects. Pipes passing through internal walls should be tightly built in or sleeved with an internal diameter of about 15 mm more than the pipe that they accommodate. Looser fitting sleeves can be packed with wire mesh or mineral fibre which should provide an effective barrier against ingress.

Services such as plumbing, ventilation systems and heating pipe work may be contained within ducts and the warmth within the ducts can provide ideal harbourage for insects and easy access to different parts of the dwelling. Ideally cold pipes (e.g. soil and cold water pipes) and hot pipes (e.g. heating and hot water pipes) should not be placed in the in the same duct as this will create a humid atmosphere which is ideal for many insect pests. An alternative solution is to position soil pipes externally although this needs careful design to ensure that it does not look unsightly.

Header tanks and other water storage tanks should have fitted lids to prevent pests using them as a water supply and falling into them causing contamination of the water supply.

EXTERNAL WORKS

Good levels of hygiene externally must be maintained to make sure that pests are not encouraged into the area. Insects may harbour under ill-fitted flagging which has not been properly bedded down. Refuse areas can attract insect pests into the area providing both harbourage and a potential food source. Residents should be provided with enough containers so that refuse need never be stored in boxes, cartons, bags or on the ground. Regular collection of refuse is also important and one of the greatest opportunities for reducing insect infestation in dwellings lies in better refuse storage and litter removal.

CONCLUSIONS

Pests are important vectors of disease and also cause distress amongst residents. Many of the current problems related to infestations can be traced to poor workmanship and bad building practice. This paper has examined the potential pest problems which may arise in the design and construction of new dwellings and where appropriate has suggested possible solutions. Many of the recommendations presented are already included in the current Building Regulations or British Standards and are easily achievable where good practice is adopted. It is hoped that by highlighting those areas where problems could arise, this paper will provide a useful checklist for those involved in designing and managing dwellings.

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