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The NEMAVO Airey system: a wealth of options

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ABSTRACT: After the Second World War there were serious shortages of building materials and trained personnel, the demand for housing was high and construction budgets were low. Together these factors created an environment for the large-scale development of non-traditional residential construction systems in the Netherlands. One of these was the NEMAVO Airey system imported from the United Kingdom and adapted for the Dutch market. This article focusses on the external walls used in this system, a combination of precast concrete columns and precast concrete cladding panels arranged on a grid, which give the Airey houses their typical appearance. The Airey houses in the Netherlands exhibit a great variety within a recognisable system. This article addresses what aspects of the construction system, historical context, system developments, parties involved, and later circumstances and interventions resulted in the wide range of remaining stock of NEMAVO Airey houses in the Netherlands.

Introduction

From their introduction, postwar prefabrication systems for house building were considered as a necessary evil (Ratiobouw 1948). Although everyone was aware that they could help solve the housing shortage, the architectural and cultural quality were disputed from the start. This applied especially with respect to the NEMAVO Airey approach, where the system largely determined the appearance. Even the architects who designed the system considered the houses to be too flat, uniform and insipid (Berghoef 1951).
However, in the past decade appreciation of the Airey houses appears to have grown. This is demonstrated by the listing of several Airey blocks as protected monuments, and recent renovations which were carried out almost as if they were restorations. Given the general need to make the housing stock more sustainable, it is likely that many more Airey houses will be refurbished in the near future. This article addresses the historical development and technical aspects of the NEMAVO Airey system and the opportunities it provided. Understanding the original system, in the current situation, can provide the foundations for future assessment and intervention.

In the early Reconstruction period (late 1940s and early 1950s) non-traditional residential construction systems were extensively covered in the trade literature

(e.g. Ratiobouw 1948). These systems were promoted by the government and publications covered their materials and technical, financial and organisational aspects. Later, the different non-traditional systems, including the NEMAVO Airey system, were documented on several occasions (Priemus and Van Elk 1970, Bouwhulpgroep 2012). The entire stock of Airey houses in the Netherlands, over 8000 units, was recently surveyed. This survey covered the location, year of construction, number of dwellings, current condition, listing status and obvious external modifications made (Quist et al. 2017).

The number, and especially the variety, of the original Airey houses and later interventions are fascinating. The discovery of this extensive variety within a recognisable system inspired further research into the NEMAVO Airey system. What are the origins of the system and how did it develop? How is it constructed and what were the premises behind it? Why do all the houses look different, although it is clearly a system? What is this system that seems to be receiving more and more appreciation?

This article addresses the NEMAVO Airey system, with the emphasis on the external walls. The key question of this study was: What aspects of the construction system, development of the system, historical context and later conditions resulted in the great variety in the current stock of NEMAVO Airey houses in the Netherlands*?*

First the context is set out within which non-traditional residential construction systems developed, and then the introduction and development of the NEMAVO Airey system are described and compared with other systems. Next we discuss the technical design of the NEMAVO Airey system, conversion of the British system into the Dutch one, and the differences between them and the reasons for those differences. Finally, the key question is: what contributed to the observed variety in the current stock of Airey houses and how can this provide a basis for future interventions?

Context

1.1 *Prefabricated construction in the Netherlands*

Even before the Second World War (WWII) there were experiments in the Netherlands to make house construction more industrial, and to introduce new materials. For example, experience with systematic house building in concrete had been gained in 1922 at Betondorp in Watergraafsmeer in Amsterdam (e.g. Kuipers 1987). The Landlust project in Amsterdam in 1937 also included experiments with precast concrete units (Abrahamse and Noyon 2007). Standardisation was tried out in Amsterdam. The General Amsterdam Expansion Plan (*Algemeen Uitbreidingsplan van Amsterdam, AUP*) developed under Cornelis van Eesteren and approved by the city council in 1939 was based on dividing the land in strips. Because of the economic downturn a cheaper, system-based construction method was developed to tie in with this urban planning concept. However, with the exception of a few blocks, the expansion was only realised after WWII.

The Reconstruction Service (*Wederopbouwdienst*) was founded in 1940, with Dr. J.A. Ringers as government commissioner charged with the reconstruction of towns and villages. New construction methods and materials to reduce the housing shortage were studied from the start. After WWII, there were serious shortages of building materials and trained personnel, the demand for housing was high and construction budgets were low. Together these factors created an environment for the large-scale development of non-traditional residential house building systems. There was a need for new building methods requiring fewer hours of skilled labour, a limited use of scarce and imported materials,

at the same or lower costs as traditional houses, and with the same quality (Ratiobouw 1948).

As rents were frozen in 1940 but the costs of building had gone up significantly, financial support from the government was needed. Prefabrication was encouraged by the government by guaranteeing the prefab builders' market and by reducing certain restrictions which meant that they could build more prefab houses than conventional ones.

The development of prefab construction in the Netherlands was the result of cooperation between structural engineers, manufacturers, architects and builders. Ratiobouw, a foundation established in 1947, played an important part in this. Under the leadership of J.P. Mazure the best industrial production methods for house building in the Netherlands were investigated. In 1946, 18 systems were used in the Netherlands and between 1947 and 1957 this increased to 360 systems (Priemus and Van Elk 1970). However, prefabrication was not universally welcomed. Although many architects assisted with the development and construction of prefab houses they also had their doubts and criticisms. According to architect Van Tijen, factory production would reduce the wealth of shapes, variety and freedom of design and hence threaten a rich culture. It was claimed that prefab houses were a product based on mass taste and commerce, which imposed themselves on architecture (Van Tijen 1948). However, Van Tijen also concluded that there was no going back, and advocated a simple, neutral architecture which was also beautiful. In a Ratiobouw publication the editors stated: “They who consider prefab as a necessary evil and they who see it as the dawn of innovation in house building can now work together in unison. Everything which is worth doing is worth doing well”. (Van Tijen 1948)

1.2 *From Airey in the UK to NEMAVO Airey in the Netherlands*

NEMAVO, *Nederlandse Maatschappij voor Volkshuisvesting,* (Netherlands Public Housing Company) was established during WWII. It was a partnership between the Ministry of Housing, large investors, building companies and industry. Its president was J.A. Ringers and H. Van Saane its director. Van Saane had set up his own construction business in 1925. He focussed on social housing which he developed and built as a 'modern project developer' (Fisher 1968). Before the war he realised projects such as Geuzenhof (1933-1940) and Muzenhof (1939) in Amsterdam, both with architect J.F. Berghoef.

In 1947 Van Saane travelled to England for a study of various residential construction systems. This study was led by J.P. Mazure. The UK was significantly ahead of the rest of Europe with the development of prefab construction as the country faced the same issues of housing shortages and a lack of resources, but had not been occupied. The advantage to the Netherlands in using British know-how was that the development and introduction would take less time and that some experience had been gained with the system.

Van Saane selected the system developed by Sir Edward Airey in Leeds and proposed developing it for the Dutch market (Messchaert 2004). Architects J.F. Berghoef and H.T. Zwiers were asked to work with De Vries Robbé in Gorinchem (steel structures and windows) and N.V. Betondak in Arkel (precast concrete), to adapt the system "industrially and architecturally" for series production in the Netherlands under the name N.V. NEMAVO-Airey (Fisher 1968). The adaptation of the British Airey system into the Dutch system started early in 1947, only a few months after publication of the British site manual for construction of Airey houses (Ministery of Works 1946). A trial house was built on the factory site in Arkel (Fig. 1).

Figure 1. Construction of the trial house in Arkel (source: Arkel and Rietveld Historical Association)

Routine production started in the middle of 1948 and in September 1948 the first NEMAVO Airey house was assembled. The premise was: "Obvious materials are selected for the components and structural design is straightforward, junctions take little work and construction demands that the workers are accurate and pay attention to their work but they need little trade skills. It is desirable if the construction of the structural walls and chimney is guided by a bricklayer, and a plasterer is required for finishing, there is little joinery to be done. Some of the construction can be done by unskilled labour, though routine will improve productivity and precision." (Berghoef 1951).

The first Airey houses in the Netherlands included those in Eindhoven Lievendaal, Gorinchem (demolished), Roosendaal (demolished) and Tiel (Priemus and Van Elk 1970). A five-year agreement with the government was envisaged, for the construction of 2000 houses per year using this system, at a fixed price. The partners intended to invest in a factory. However, the government only wanted to make limited price agreements and to conclude a contract for 6000 houses in five years, with a fixed price for the first 3000. Consequently, series production never really started and there was only a limited amount of prefabrication. The production of components started in the factory at Arkel, which was convenient given the location of the first houses. Soon production moved to an open air factory in Amsterdam given the high production in that city. Later, a factory building was constructed at the open air site (Priemus and Van Elk 1970).

1.3 *Further development of the NEMAVO Airey system*

The types of non-traditional residential construction systems used in the Netherlands can be divided into three categories: stacked construction, using small components supplied to the site which are stacked (wet or dry); casting, where concrete is poured in temporary or permanent formwork; and prefabrication, where special prefab units (small, medium or large) are used (wet or dry) (Polytechnisch Tijdschrift 1959). With most systems, the difference between traditional and

prefab construction relates to the primary structure of the building, often combined with traditional finishes (including the external wall finishes). The NEMAVO Airey system may be considered as a hybrid between stacked and prefab construction, and a non-traditional system is used for the external walls (Priemus and Van Elk 1970). The Dôtremont-Ten Bosch system is a similar non-traditional system with load-bearing external walls. This French/Belgian system was used by architects Merkelbach and Elling for the Jeruzalem project (Frankendaal-Watergraafsmeer) (Zijlstra 2003). It has many similarities with the NEMAVO Airey system. However, the Dôtremont-Ten Bosch system uses concrete components throughout, while the Airey system also uses steel.

Despite the development of many new construction systems, in the late 1950s only a few were viable enough to gain a permanent foothold in house building (Polytechnisch Tijdschrift 1959). Surprisingly, the Airey system only received Ratiobouw approval in 1962. By that time the main wave of construction had finished and the five-year contracts for lightweight building systems were not extended (Lijbers, Thijssen and Westra 1984). After 1 January 1969 grants were only provided for a few prefab systems (Priemus and Van Elk 1970). As a result, NEMAVO Airey and variations on it disappeared from the market. NV Mesa, Maatschappij *tot Exploitatie van het Bouwsysteem Airey*, (Company for the Exploitation of the Airey Construction System) in Ten Post, Groningen continued using the system from 1966 to 1978, primarily for bungalows. In total, between 1947 and 1966, over 8000 houses were built in the Netherlands using the NEMAVO Airey system and the MESA system (Quist et al. 2017).

Technical aspects

1.4 *Airey houses in the UK*

This general description of the original Airey system is based on the description by Berghoef (1951), a handbook by the Ministry of Health (1947), a site manual by the Ministry of Works (1946) and fragments from the documentary Country houses by Paul Dickson (1947). The system was first developed in the 1920s and apparently some 26,000 houses were built with it in the UK after WWII. The description below concerns the system structure in the late 1940s.

Figure 2. Typical British semi-detached Airey house

In the UK, Airey houses were often built as rows of detached or semi-detached houses, in rural or suburban settings (Fig. 2). The foundations were constructed on site after which the houses were assembled. First, three rigid concrete beams with three legs were installed for each floor of each house. A lattice girder was then fitted between the centre legs. Prefab concrete columns to the full floor height were then installed between the legs in the outer walls. The columns had a round steel tube as reinforcement and were fitted with a wooden batten on the inside, to fix the internal finish. The columns were installed at 1.5 foot (457.2 mm) centres. The exterior walls received prefab concrete cladding planks with wire reinforcement and a pebbledash finish. After striking the

formwork the reinforcement on the back was bent into hooks. The cladding panels were secured to the concrete columns using wire wound around these hooks. A thick bitumen-based caulk was applied between the columns and panels, for waterproofing and bonding. The panels look like they are ship-lapped but actually have a smooth back surface and their thickness increases towards the bottom which also has a rebate. Consequently there is only a small overlap between panels. Inside the house the concrete columns were finished with aluminium foil for insulation and panels (Fig. 3).

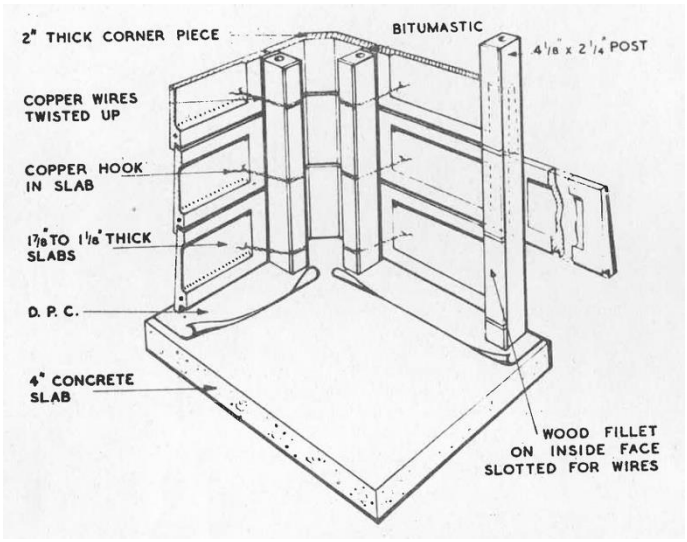

Figure 3. Axonometric drawing of assembly of the Airey system (source: Site manuals for prefabricated houses*)*

Aluminium windows were installed on the outside of the columns, flush with the outer face of the wall. This left a clear opening of only 350 - 400 mm but meant no lintel was required. At the front door there was a break in the grid of wall columns where a lintel was fitted to get an opening of adequate width. The interior walls were traditional stud walls, except for the wall by the third leg of the beam, this also incorporated concrete columns. The system used concrete floor joists fixed to the columns using metal components. The roof was of traditional timber construction, often with fibre-cement slates. The tip of the side elevation was also clad with timber or fibre-cement slates.

1.5 *NEMAVO Airey*

In 1951, Berghoef described the NEMAVO Airey system in detail in *Forum*, an architectural journal. He noted that the system, and the houses built with it, was subject to continuing technical development. The description below is based on Berghoef (1951).

According to Berghoef, the foundations, brickwork interior wall (lightweight bricks or other materials) and plasterwork were definitely not part of the Airey system. In structural engineering terms, the frame can be considered as a table with many legs. The table top (the floor) is rigid as the timber components are nailed to the steel lattice girders which are rigidly connected to the steel edge beam. At the edges the legs are clamped such that the whole table is rigid and resists horizontal forces. If the span is too large for the lattice girders then a beam is installed at the centre to support them, and itself has one or more supports: legs in the centre.

Berghoef identified the advantages over the original Airey system: the edge beam gives more freedom in positioning the columns and lattice girders; they need not be aligned. The spacing of the joists and interruptions in them are also unrestricted. The columns can be installed at any spacing, this facilitates larger windows, and additional columns can be placed where required. For more floors, more tables are stacked on

top of each other, up to four floors. When building more floors the support beam and legs are replaced by a steel frame. As a result the concrete columns are suspended and only serve to support the cladding panels. This makes it possible to construct taller buildings, such as the tower in Sloterhof in Amsterdam.

Figure 4. Facade with concrete surrounds (Photograph: Carel Blazer, provided by the Amsterdam City Archives)

Initially, steel windows were fitted to special concrete frames (Fig. 4). These were heavy, awkward to handle and difficult to produce. After a year and a half a special profile was fixed to the jambs of the steel window frames. This was not surprising with De Vries Robbé, who manufactured steel windows and other products, on the development team. Berghoef commented: "This was a benefit in structural engineering terms, but in aesthetic terms there was not only a gain but also a serious loss as the white frame between the grey wall and the steel window was lost. This posed a difficult problem for the architects: the outer walls, already very flat, lost the remaining relief at the windows, and also colour as a tool; their consolation was that they had much more freedom in placing the windows than before." (Berghoef 1951). However, at Sloterhof, Berghoef used a bright white concrete surround with a steel window fixed inside it at the factory.

In his article Berghoef did not identify the cladding material; presumably this was generally known, or Berghoef assumed this to be the case. However, he included a detailed cross-section from which we can conclude that the cladding consisted of concrete units 40 mm thick, 400 mm high and 600 mm wide. Using bolts these were hung from eyebolts fixed to the concrete columns. Berghoef explained that he considered the facades to be too flat: "A difficult issue is that the facades are very flat and consequently the whole appears to be a cardboard cut-out. The reveal by the front door, a few balconies here and there and that external chimney by the end wall help a bit, but there is still little plasticity. There are two remedies: offsets, preferably clear ones, in the building lines and the addition of plastic elements to the streetscape: posts, hedges, bushes and trees. The latter are particularly effective with these light-coloured, stark houses, because of their colours and irregular shapes. Taller buildings have semi-recessed balconies which are almost essential to creating plastic rhythm in long elevations. There were differences in ground level in some N.-A. [NEMAVO Airey] developments: these were used effectively. However, it was found that the road layout, property lines, division of the site and planting, in short, the entire urban arrangement, are key to the appearance and character of the N.-A. complexes". (Berghoef 1951).

The reinforced concrete columns have a length close to the floor height, a width of 62.5 mm, and are installed at 625 mm centres. The reinforcement is provided by a continuous steel tube, with two bolts welded to it for fixing the steel edge beam. Holes are provided for fitting the eyebolts to fix wall cladding. At the rear there are two treated wooden battens, 20 x 25 mm, for nailing the internal wall panels. The reinforced concrete cladding units have an effective height of 375 mm and an effective width of 625 mm. The thickness and edge detailing varied. In general the thickness was 40 mm, but there are also units where only the edge had this thickness. The units have four cast-in internally threaded bushes for fixing to the columns. The edges are slightly bevelled, leading to a wedge-shaped vertical joint. The top and bottom edges have mating rebates. The inner leaf was always masonry, with or without insulation (Fig. 5).

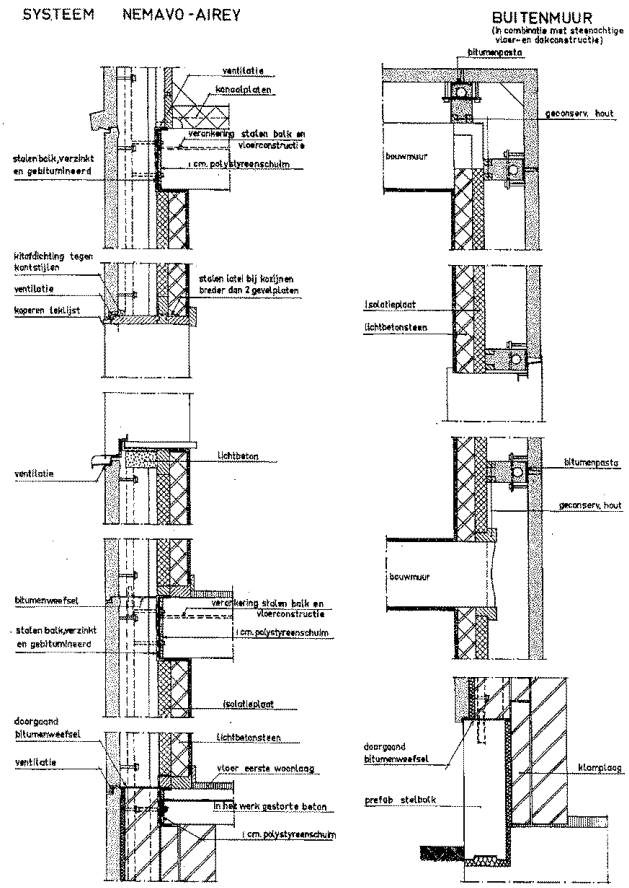

Figure 5. Cross-sections in the Ratiobouw approval document, 1962 (source: Van der Heijden and Klomp (eds.))

1.6 *MESA*

The main difference between the NEMAVO Airey system and the MESA version was the introduction of a steel supporting beam from the front wall to the rear wall, connected to the edge beam and to traditional wooden joists parallel to the front wall. The steel lattice girders were dispensed with and to obtain the longer span a steel H-beam was used. The design of the back of the cladding units was also different. Between insulating panels and an inner leaf of plaster blocks, aluminium foil was placed. The cavity had openings at the top and bottom of the walls for ventilation (Priemus and Van Elk 1970).

1.7 *Differences between the British and Dutch systems*

A comparison between the British Airey system and the Dutch NEMAVO Airey system shows many differences, large and small. The structural design changed from a series of portals to a table structure, and different materials were used for the foundations, floors, walls between dwellings and the interior walls. In the Netherlands there were also differences in these areas. Hence it might be concluded that the NEMAVO Airey system was primarily an exterior wall system. When comparing the British and Dutch systems we notice some clear differences, especially in terms of the dimensions. The distance between the wall columns (grid module) was 450 mm in the UK and 625 mm in the Netherlands. In contrast, the cladding panels were narrowed, to the module spacing. The panels were larger and flat. Hence the appearance changed from long shiplapped strips to a flat grid pattern. The Dutch system allowed for 'hanging columns' over window frames so that these could be two module units wide.

The reasons for these changes are due to differences in housing culture. According to Berghoef, the narrow windows with breast walls one metre high would be '"poorly received". Small, narrow windows were incompatible with our tradition of housing. Dutch architects aimed for larger openings and more freedom in wall layout. The shape and slope of the roofs and type of roofing differ between the two versions. Berghoef explained this by referring to the cultural differences between the UK (traditional) and the Netherlands (more modern).

The main difference between the Airey houses and the NEMAVO Airey system was the change from a prefabricated house system to a construction system. In the UK the end product was a house, albeit with some minor variations, while in the Netherlands it was a construction kit (Van der Heijden and Klomp 2004). In the UK most of the houses were semi-detached while in the Netherlands there was a wide variety in types. Although terraced houses and middle-rise blocks of flats dominate, the system was also used for semi-detached houses, housing for the elderly, tower blocks,

maisonettes on galleries, bungalows, commercial buildings, garages and storage sheds.

Variety

1.8 *Development of the system*

Studying the development of the British Airey houses into the Dutch NEMAVO Airey system is the first step to answering the key question of this article: "*What aspects resulted in the great variety in the stock of NEMAVO Airey houses in the Netherlands?*" In the Netherlands it developed from the British prefab house into a construction system with load-bearing exterior walls which, due to the carefully-chosen module size and load-bearing edge beam, offered great freedom in the layout of both the plan and elevations.

This construction kit could be used by architects making site-specific designs, in a range of dwelling types, block dimensions, repetition and mirroring, corner solutions, composition of the elevations and details. The architects Berghoef and Zwiers probably also had their personal styles, though this is not particularly apparent. Even before the system was actually introduced in the Netherlands it was announced that, although the British Airey houses were considered to be architecturally acceptable, a number of leading architects would be engaged to design variations (Bouw, 1946). It is likely that the eventual variety went beyond the initial expectations. The Sloterhof development in Amsterdam, designed in 1954 by Berghoef, is the best example of this variety, both in terms of typology and detailing (Fig. 6). Here the Airey system was used for a range of dwelling types, low and high rise, and shops, garages and petrol stations, and there is a wide variety of balusters, window surrounds, roof edges, panel dimensions and colours. It was nationally listed as a monument in 2016 (Rijksmonumentenregister 2017).

Figure 6. Variety in detailing and typology in Sloterhof,

Amsterdam. Photograph: Hielkje Zijlstra

In addition to using the design freedom provided by the construction system, the experience gained during construction projects helped the development of the system and therefore promoted variety. The elimination of the concrete surrounds around the window frames is an example of this. Doubts about the aesthetics also encouraged architects to include as much variation in their designs, e.g. in the rhythm of the elevations.

1.9 *Interventions*

A long time has passed since the construction of these houses. In the Netherlands, Airey houses were built between 1948 and 1965 and are therefore now over 50 years old. The recent survey indicated that practically all elevations have been modified in some way. Sometimes only the front door was replaced, but elsewhere the appearance of the houses has changed so much that they are almost unrecognisable (Quist et al. 2017).

The extent of the interventions varies. Some houses are almost unchanged, for example where only the roofing was replaced. However, most of them have

undergone clear changes to the elevations. Necessary maintenance and personal preferences have resulted in the replacement of front doors, windows, downpipes and roof edges by different products (Fig. 7). Both technical issues and the appearance of the Airey houses have led to interventions. The walls have been painted at many sites, sometimes in white, sometimes each block in a different colour. A more extensive, common intervention is the replacement of the concrete cladding panels by insulation with a new finish such as render, wooden cladding or brickwork. This eliminates the characteristic grid of the elevations.

Figure 7. Variety by individual alterations in Oostzaan, Amsterdam. Photograph: Hielkje Zijlstra

In some projects the typical Airey appearance provided inspiration. For example, the cladding panels were replaced by tiles in a different colour and material. The more recent examples include refurbishments where the external walls were upgraded while maintaining the original concrete cladding panels. In these cases the insulation was installed in the existing cavity (between the wall columns) or on the inside of the columns. There is a trend of renewed appreciation. The cladding panels are stripped of paint, repointed, cavity insulation is installed, and retrofitted PVC windows are replaced by wooden windows or slender aluminium ones. The intervention strategy followed when refurbishing Airey houses appears to be shifting from pragmatic maintenance driven by technical considerations towards greater appearance and the intention to preserve the typical Airey appearance (Fig. 8).

Figure 8: Cleaning, repointing and post-insulating Airey houses in Amersfoort. Photograph: Hielkje Zijlstra

1.10 *Conclusion*

The great variety in the remaining stock of NEMAVO Airey houses in the Netherlands is the result of several factors: the development into the Dutch system as a construction kit, the freedom which architects such as Berghoef and Zwiers and their clients applied in each design, the gradual changes in the construction system, and the different reasons, requirements and trends of owners and architects at the time of later interventions. This study did not address if there is a clear relationship between the type of intervention and the characteristics of the original buildings. Further studies could indicate if certain types of houses or details resulted in the same type of interventions, and what characteristics of the NEMAVO Airey system led to interventions.

Notes

This article is based on the study *NEMAVO Airey - kernkwaliteiten en transformatie mogelijkheden* (NEMAVO Airey - key qualities and options for transformation) undertaken in 2016-2017 by W.J. Quist, H. Zijlstra and L.G.K. Spoormans at TU Delft, Heritage & Architecture, commissioned by the Cultural Heritage Agency of The Netherlands.

The photograph of the British Airey house (Fig. 2) was found on several web sites but we are unaware of the source. The holder of the rights in this picture is invited to contact us.

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