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Panel Buildings Torn between Demolition and Rehabilitation

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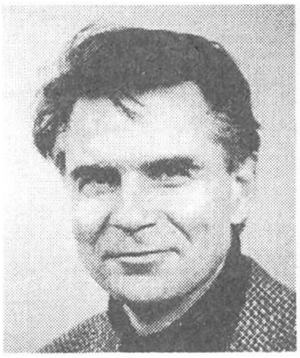

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1. Introduction

The paper focuses on the following topics: First to the dimensions of panel building construction, then look at the structure of the existing stock, at the subject of repairs, costs and sponsorship development and finally at examples for a process of upgrading and revitalisation. Ecological aspects of building are not omitted, and the presentation concludes with "directions for action". Building is a central issue in our society. Building attracts the attention of newspaper readers on the pages covering politics, culture, science and also sport when it is a case of building stadia or organising Olympic Games. Every society is reflected in what it builds. *One invested Mark activates 2.40 DM.* Economists tell us that the upstream and downstream sectors of the construction industry have to be rated with a factor of 2.4. One invested Mark activates DM 2.40, a billion's worth of investments creates 13,000 jobs.

2. Cities within Cities

If one considers Berlin-Marzahn - a giant housing estate with endless rows of housing blocks, all eleven storeys high, a perpetual repetition; monotony which is depressing. Marzahn has 59,000 dwelling units. Assuming 2 to 2.5 persons per dwelling unit - that means that entire cities within Berlin are without an adequate social and cultural infrastructure - how should one address these prefabricated panel buildings in terms of their conservation, their upgrading and their future? First, a detailed analysis of the existing buildings needs to be undertaken if one hopes to arrive at solutions for conserving, improving and upgrading them.
A total of 7.04 million apartments exist in the new German Länder. 2.17 million of the apartments are contained in prefabricated buildings, 2.58 million apartments are found in conventionally built multiple-dwelling units and 2.29 million apartments exist in single and two-family houses. The latter categories are also faced with serious problems, however the present survey only concerns prefabricated construction - often referred to under the collective term "panel building construction" - with just over 2 million dwelling units.

No WBS building has to be demolished
After the opening of the Wall everyone said that the panel buildings had to be demolished because they were unstable. However, a rational consideration of the problem based on the housing stock analyses that have been undertaken shows that not one panel building has to be pulled down for technical reasons. The IEMB (Institute for Rehabilitation and Modernisation of Buildings) has analysed and documented these findings, as have other experts.

1. Repair	2. Partial refurbishment	3. Complex reconstruction	4. Luxury reconstruction
Elimination of damage/ Correction of defects	Repair + partial refurbishment (mainly of the common consumer systems)	Extensive modernization	Extensive modernization and special measures
Measures in stage 1	**Measures in stage 1+2**	**Measures in stage 1-3**	**Measures in stage 1-4**
Stufe 1: ▪ Joints ▪ Roof ▪ Windows/doors ▪ Sanitary ware ▪ Other structural elements acc. 3. Bauschadensbericht	**Stufe 1** **Stufe 2:** ▪ Facade / thermal insulation ▪ Entrace hall/corridors (possible with lifts) ▪ Rising mains (stacks) ▪ Central heating plant ▪ Fire protection measures ▪ Repair of balconies (including renewal of the balcony wall unit) ▪ Valves of radiators ▪ Repair of windows (possibly renewal)	**Stufe 1** **Stufe 2** **Stufe 3:** ▪ Bathrooms/kitchen (sanitary ware/tiles) ▪ Electrical installation (renewal / extension) ▪ Renewal of windows ▪ Renewal of building entrace and apartment unit doors ▪ Radiators / heating pipes (as required) ▪ Creation of a new, high quality environment	**Stufe 1** **Stufe 2** **Stufe 3** ▪ Changes of layout / joining or separation of apartments ▪ Extension or renovation recessed balconies/glazing ▪ Building of completely new bathroom/additional WC ▪ Sound insulation of walls/ floors ▪ Installation of passenger lift ▪ Completely new entrance area
COSTS			
Appr. 100-400 DM/sq.mtr floor area	Appr. 300-750 DM/sq.mtr floor area	Appr. 600-1200 DM/sq.mtr floor area	Appr. 1500-2500 DM/sq.mtr floor area
Measures of occupied buildings			... of unoccupied buildings

Stages of reconstruction for unit and panel building structures in the new German *Länder*.

In order to reduce the CO_2 emission in Germany by a quarter by the year 2005, older buildings would have to be reconstructed at an annual rate of 3 %.

In 1990 room heating for the entire housing stock and small consumers accounted for approximately 28% of the primary energy consumption in the new German *Länder*. The total CO_2 emission accounted for some 15 % of their national economy.

The implementation of measures to reduce energy consumption in the shell (thermal insulation, windows) and of the service installations led to a reduction of the annual heating requirement by 30 - 50 %. Fig. 9 contains an overview of representative types of industrial housing construction, of which about 80 % are supplied with a long-distance heat supply. In terms of energy they are characterized by different initial statuses as regards structural thermal protection and heating engineering.

As regards the total energy balance of a building, which is derived from the manufacture, operation and finally demolition - interrupted at any time by refurbishment and reconstruction measures - the panel buildings are in a favourable range. The figure summarizes the conclusions that can be drawn.

The conservation, reconstruction and long use of existing building substance protects the environment

- ❑ Saves energy
- ❑ Reduces CO_2 and pollutant emissions
- ❑ Reduces intervention in the soil and groundwater
- ❑ Reduces the need for waste disposal sites

My last point is a kind of "direction for action". It is a quotation of Paul Valéry: "Poorly observed facts are worse than wrongly drawn conclusions". A doctor cannot diagnose a patient over the phone, he needs to see and examine the patient. In principle. the same applies to the analysis of a structure. Engineers bear the responsibility for analyzing buildings and structures in a rational manner. Only then should they draw conclusions on how to handle them.

Rehabilitation Methods for Residential Buildings

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Summary

In the sixties in most larger cities of northern Italy we had a firm growth of public housing. Many residential district, that grew close to the industrial sites, were distinguished by prefabricated buildings, mostly made of concrete prefabricated panels. Nowadays most of these buildings presents deep deterioration and performance losses. Therefore a deep restoration is now required but is a complicated matter. If we test a sample of these buildings we can notice a series of heavy inadequacies, compared to topical residential requirements. A large number of these inadequacies concerns the habitability of flats, in term of flexibility, the environmental confort condition and the building pathologies connected with construction faults. These faults might be caused by design mistakes or by a wrong execution. Our method consists of an analytical approach and of a following program of building's rehabilitation.

Keywords: Performance loss, pathology, load - bearing panels, virtual model, real model, indicators, classes of values, conform solution, strategy of intervention.

1. Research Methodology

The renovation of the existing real estate, which consists of building systems with different technologies and morphologies, is a complicated problem of quality in construction. The intensive urbanisation of past years, due to speculation or ideology, shows the need of planning over the outskirts of our cities. The degradation of the urban context is a peculiarity of several residential areas close to the historical centre. In such a negative situation for the environment and for the users we really need to think over the building organism and its relation with the urban system. We must start from the general requirements and the needs of the users. The deep knowledge of our buildings is indispensable for the restoration process. Remodelling the interior (environment) and the container (building system), one encounters values and angles of different disciplines. The complexity enlarges retraining districts with prefabricated buildings, both for social consequences, for reduced performance standards and for the capacity to set off pathologies and environmental degradation.

At the Politecnico of Milan - DISET - we researched a method in order to define the operations for the improvement of real estate residential buildings, as result to our rich previous experience on this theme. Our aim for a new housing concept moves from these four main features:
- a home where to spend more time (identity)
- a home custom made (flexibility)
- a healthy home (salubrity)
- a sustainable home (conservation of natural resources).
The common principle is the relation between users and home, and between home and its context, that breeds a relation between the inside and the outside and improves the living quality.

At the beginning of the 60's the "Istituto Autonomo Case Popolari of Milan", to stand up to the considerable request of houses to be built in a short time - 25.000 units in 5 years - started the construction of buildings with prefabricated load-bearing concrete panels. A market research of the prefabricated construction types available, suggested the selection of the French types Balency, Barets, Camus, Caignet and Fiorio, because they best fulfilled the technological and formal requirements. The Italian contractors have acquired the manufacturing licence, thereafter introducing some technological and distributional modifications. Therefore we have a common background for the considered interventions, which are derived from a constructive system. This is very important for our research methodology. As a matter of fact those elements which may be considered lacking in the considered real estate are methodically dispersed and are referable to the following principles:
- Inadequate typological distribution: apartment size, unit composition, bathroom and kitchen supply, flexibility of use for the various and changing needs of the customer.
- Physio-environmental quality deficiencies: hydrotermal, acoustic, energy efficiency and visual comfort.
- Transformation of the urban context with a considerable change of the stress conditions operating on our buildings.
- Pathologies due to congenital building defects and to dilapidation with time.

A research program regarding the operational strategies of real estate maintenance is a complex issue that involves all the branches of design and building technology. Our team has set up a comprehensive and effective method that clarifies the outlines for maintenance where each operational case and each stage of the process is reduced to an organised system. First we had to face the constituents of the problem, which are: processing, spatio-functional issue, environmental-technological issue, economical issue. In correlation we identified 5 indicators of performance loss, to which all quantitative and qualitative parameters have been referred:
1) Risk: as an indicator of the probability of the occurrence of events that may be harmful to the users.
2) Pathology: as an indicator of building system failures and abnormalities.
3) Discomfort: as an indicator of a deficiency in the well-being of the inhabitants.
4) Dilapidation: as an indicator of normal and predictable decay of buildings.
5) Obsolescence: as an indicator of a drop or loss in the functional efficiency due to new needs.

Our method consists of two different stages of analysis on the residential estate. The first test is on the original design and has a systematic character. The result of the reconstruction of the project, referring to the requirements and the provisions of that time, is a "virtual model" that shows the original spatial, environmental and technological characteristics of buildings, manufactured through a common type of concrete bearing panels. The second test is on a sample of buildings and has a phenomenological characteristic: it consists of recording deterioration and pathologies that eventually occurred using the buildings: the result is a "real model".

Upgrading of Residential Buildings in Precast Construction

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Wolfgang Steger, born in 1945
Dresden Technical University in 1970, thesis in 1976.

Summary

The housing stock was erected in industrialised precast construction in central and East European countries, particularly in the new German federal lands, over the years since 1955. It will be lasting far beyond the year 2000, thus offering the tenants a home. Constant repair and modernisation are the prerequisite for a long service life of all buildings. With regard to the so-called panel buildings a basic upgrading of the housing stock will be required to ensure a letting in the long run.

Keywords: Panel buildings in precast construction; modernisation; repair; balconies and loggias, steel and concrete floor; railing of aluminium and steel; complete reconstruction of panel structures; new plans for flats

1. Concepts for Upgrading the Residential Amenity of the Panel Structures

At the present time, about 2.2 million existing panel structures are comprehensively repaired and modernised in the 5 new federal lands, including Berlin.
The main tasks in doing so are as follows:

- roofs and basement walls are insulated,
- façades are given thermal insulation with insulating systems, thus treating concrete damages caused by corrosion,
- balconies and loggias are structurally secured, upgraded in their colours, provided with new parapets or disassembled and erected anew,
- building entrances and staircase wells are newly designed and
- kitchens and bathrooms are modernised comprehensively as well.

Today, some residential homes are basically reconstructed in the course of privatisation. The flat plans are changed in their horizontal and vertical level by cutting open the floors and load-bearing walls. By way of building in the staircases between the living levels, also other housing forms are offered within the stock of panel buildings.

Entire residential areas are decisively upgraded by design possibilities in façade repair as well as by parapet design and new construction of balconies. The examples executed show that the residential amenity of these housing areas is highly appreciated by the citizens and a growing demand for dwellings is to be seen there.

2. Complete Solutions for Placed-in-front Balconies and Loggias

Compared to all structural units in a building, balconies and loggias are most severely exposed to the loads of the 4 seasons. At the same time they have to meet the demands on a roof skin, façade, floor, load-bearing structure as well as on the removal of rain water and are decisive for the residential amenity and the impression of a building as a whole.

For the client and architect the fulfilment of these complex requirements is decisive what balcony solution is chosen. Individual design, functionality, structural stability and service life are the dominant fundamentals for deciding on a balcony solution.

To them belong	**complete balcony installations** in steel, aluminium and reinforced concrete, placed in front of the house, built in or retrofitted, connected with the façade in an optimal manner structurally and functionally,
	balustrades for all application cases, in all forms, endurable materials and fastening modes, colours and coatings,
	balcony glazings, partition walls and linings.

Experience showed that balconies will be placed in front of a house in case if repairs to existing balcony installations will not guarantee a service life in the long run. Moreover, the erection times become increasingly a criterion of decision-making. As a matter of fact, inconvenience for the tenants followed by rent reduction and judicial hearings right up to the moving out from the dwelling, as well as liability disputes are expensive.
New balconies and loggias (see Fig. 1) ensure:

- a design upgrading of the residential buildings in accordance with the client's ideas and the architect's designs,
- adaptation of the usable balcony area to today's requirements,
- decisive increase in service life by high-grade materials,
- assembly and completion services without the need for entering the dwelling,
- retrofit of balconies to improve the tenantability and residential amenity,
- use of railing and parapet variants, as well as glazings.

2.1. Balcony Structures

Balconies made of reinforced concrete are produced in moulds with a concrete grade of not less than B 35 WU (waterproof). The casting is supervised in concrete factories near the building sites and has to comply with the "Generally recognised rules of technology". The German Award Rules for Building and Construction Work (VOB), part B and C in their latest version, make up the fundamental data for contracts.

Modernisation and Strengthening of Large-Panel Building

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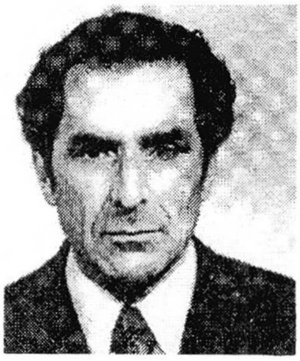

Eduard Alexandrian, born 1919, civil and industrial engineering, candidate of technical science. For over 30 years has studied the problems of strengthening and restoration of damaged buildings.

Summary

The paper describes modernisation of a large-panel building, series 1-335 in Krasnodar. Attention is paid to the structural solution of such buildings and the design drawbacks which resulted in significant corrosion of important joints of bearing structures, overnormative deflection of floor slabs, etc. The paper presents developed, tested and introduced solutions on elimination the drawbacks of the structure. Also considered are the questions of durability and reliability of epoxy mortars in construction based on the results of long-term studies of the author and observation over the operation of the buildings restored and strengthened by epoxy mortars.

1. Modernisation of Large-Panel Buildings, Series 1-335 in Krasnodar (Russia)

In the process of building and exploitation of large-panel buildings of series 1-335, one of the mass building series of the first generation in the former Soviet Union, an urgent necessity of solving a number of architectural and structural problems arose. Besides that these houses deteriorated and required overhaul repair and modernisation. The structure of these houses consists of outside wall panels and inside frame, the main elements of which - cross-bars - are supported by the columns spaced along the middle longitudinal axis of the building and by the outside bearing wall panels. The wall panel presents a thin ribbed slab 30 mm wide with warmth-keeping jacket of non steam cured foam concrete 300 mm wide. The load from the cross-bars to the outside wall panels is transferred through the cantilevers made of channels N12 embedded in the ribs of the panels with the cross-section 175 x 150. The floor slabs, width 100 mm, are supported from both sides by cross-bars, cross-section 200 x 350 mm.

Presented below are the solutions of a number of technical problems developed by TbilZNIIEP concerning the elimination of structural drawbacks in the buildings of series 1-335. The solutions were approved in Krasnodar (Russia) in 1989 in one of the first experiments in the Soviet Union on the Modernisation of large-panel buildings of the first generation.

1.1 Strengthening of the joints "Cross-Bars Supported by Wall Panels"

Examination of the buildings of series 1-335 after 10-12 years of operation in different towns revealed corrosion of load bearing embedded details of channels N12. In Leningrad, e.g., corrosion was 0.5 mm on the average on every open surface amounting to 1 mm in some places. Corrosion of the embedded details was mainly due to the "bridges" of cold formed in double-layer panels due to the wrongly selected warmth-keeping jacket of non steam cured foam concrete of low strength, weak adhesion with reinforced concrete panel and high hygroscopicity. Taking into account the danger of exploitation of the buildings with such joints it was suggested that reinforced concrete monolithic or prefabricated columns 200 x 200 mm, height 2.20 m should be placed under existing cantilevers on each floor and additional foundation should be arranged with the column in the sub-floor /l/ (LenZNIIIEP). This method alongside with great labour expenditures was connected with the necessity of erection of long-size column elements through window openings. TbilZNIIEP has solved this problem by gluing prefabricated reinforced concrete elements - cantilevers to the wall panel ribs - by means of polymer mortar against the stop to the existing cantilevers. Anchor free lengths of cantilevers were glued into the pits previously drilled in the ribs (fig. 1).

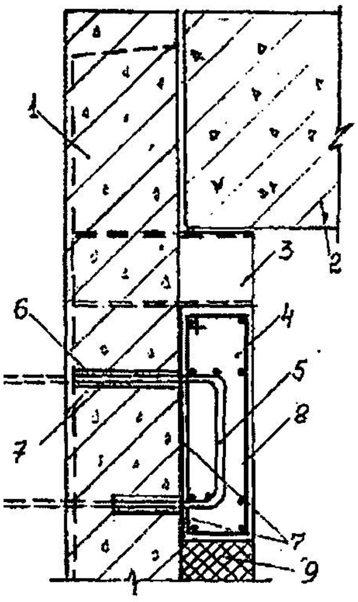

Fig. 1 Strengthening of the joint 'cross-bars supported by wall panels'
1 - wall panel rib; 2 - cross-bar; 3 - channel No. 12; 4 - strengthening cantilever; 5 - anchor; 6 - pit, d = 25 mm; 7 - polymer mortar; 8 - cantilever reinforcement, 9 - warmth-keeping jacket-foam concrete

To fix the newly built loggias to the existing wall panels from the yard facade anchors of the cantilevers were roved through the pit in the rib and welded to the embedded details of the previously arranged vertical panels of loggias. Shear tests of a full-size reinforced concrete cantilever glued to the panel rib fragment showed that the patterns were damaged mainly in tile concrete close to the glue joint and anchor rupture. The bearing capacity of the strengthening structure was 1.5 - 2 times that of the designed one determined according to /3/ as the design of an embedded detail. Hence the design of anchor cross-section area of the strengthening cantilever can be analogous to he design of anchor cross-sections of embedded details /3/.

Having found the area and the diameter of the anchor - d and assuming the diameter of polymer mortar casing - d_o it is possible to determine the length of the anchorage of free lengths of reinforcement bars of the cantilever - l by formula

$$l \geq \frac{d^2 R_s}{4 d_0 R_{b,sh} \gamma_{bi}}$$

where R_s - designed stretch resistance of the reinforcement, $R_{bs,h}$ -actual strength of concrete: panel rib shear strength assumed to be $R_{bs,h}$ = 1.58 R_{bt} where R_{bt} -tensile strength of concrete

Renovation of Prefabricated Concrete Elements: Nikolaiviertel in Berlin

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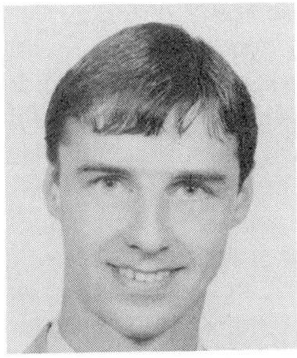

Cornelius Scheidges, born in 1957, received his PhD in Chemistry from Technical University Berlin in 1986. From 1987 to 1993 he worked with the Schering AG as a research chemist. 1993 he joined Euroteam GmbH, were he became General Manager in September 1997.

Summary

Over 30 millions of apartment units in Eastern Europe are built of prefabricated concrete elements. This type of building shows a good general performance in respect to cost effectiveness, shape of the units and durability, but has some typical constructional weaknesses, that are similar in all eastern European countries including the former GDR. A major problem represents the joint construction between the elements, where leakage leads to concrete corrosion, water intrusion and a function loss of the thermal insulation. On the example of the Nikolaiviertel in Berlin a system for facade renovation is demonstrated, that combines cost effectiveness, long term performance of the joint sealing system and concrete protection with the option of colour design.

1. Introduction

When Germany was reunited, in East Germany a stock of **2.1 million** of prefabricated element **apartments** was waiting for renovation. In the first stage the technology of joint tapes was widely used to fix leakage of prefabricated facades. Later, in the second phase, the housing companies began to modernize their houses systematically, started with the oldest buildings and added mainly external insulation systems (**EIFS**). Currently, in the third phase, the modernization of approx. **750,000 units** with **sandwich elements** is going on. Here in many cases the internal insulation is in good shape and addition of EIFS gives no economic advantage. This is, why a growing number of Housing companies chooses for the facades the **combination of joint tapes, concrete repair and elastic facade colours**, which is the subject of the following paper.

2. The Joint Tape

In Germany three major types are available: **Polysulfide Tape** (market share approx. 70 %) **Silicone Tape** (market share approx. 20%) and **Polyurethane Tape** (market share approx. 10%). Best in UV-stability and weatherability are silicone and polysulfide tapes, best in mechanical properties are polysulfide and polyurethane tapes.

All types are glued with adhesives, that have the same material basis as the tape itself and are mounted on clean and dry surfaces. The substrate may be concrete, brick, ceramic tiles, aluminium, wood, renders etc.. Before the tape is installed, the adhesion zones are treated with a primer (different types, depending on substrate).

The tape is positioned over the joint so that at both sides a 20% wide part of the tape is glued on the substrate and an elongation part (approx. 60% of tape width) is kept free to take up the expected movement of the elements. Tapes are available from 25 mm to 300 mm width.

3. The Facade Renovation System Based on Joint Tape

The system combines **three elements**. A polymer coated concrete repair system (**PCC-system**) that includes a primer compound, a standard mortar, a fast setting mortar and a smooth render. An elastic, crack bridging, UV-curing **acrylic facade coating** system that includes a solvent free primer and two layers of elastic coating. The **joint tape** in combination with facade sealants.

4. Advantages of the Tape Facade System

Reduction of Central Heating Costs: The typical sandwich element suffers from leakage of the joints and wet internal insulation. By covering the wall elements with the elastic colour and closing the joints with tape, water intrusion is completely stopped. In praxis this leads to a reduction of the "k - value" (W per m^2 and K, unit of heat conduction) from 0.85 (typical value for an untreated, "wet" sandwich element) to almost 0.65 (theoretical k - value for the "dry" sandwich element). If the facade treatment is combined with exchange of the windows and additional roof and cellar insulation, it is possible to reach for a typical sandwich element building of the early 1980ies the energy status, that is required by German law ("Wärme-Schutz-Verordnung) for houses built after 1995.

Durability: The tape has a proven life expectancy of more than **20 years**.

Architectural Design: The colour/tape system offers to the designer the full variety of options as the EIFS do. However the character of the buildings is not getting lost, what is already an issue in Germany.

Cost advantage: The cost per square meter facade depends on the status of the building, the geometry of the facade, the over all volume of the project and many other factors. However, in East Germany the average price can be estimated for EIFS with **120 to 150 DM per m^2** and for the colour/tape system with **65 to 80 DM per m^2**.

5. General Outlook / Conclusion

Most of the sandwich element buildings in East Germany are in relative good shape and show only moderate to light concrete damage. The financial situation of the housing companies, the communities and the people who live in the houses is already stressed and is expected not to improve, eventually to get worse in the coming years. This lead in the last two years to a strong trend towards the **tape facade system** with already **10000 - 20000 apartment units** renovated according to this method. With almost **50% of cost savings** compared to EIFS it represents a fair compromise between technical performance, aesthetic appearance and economic value.

Rehabilitation of Sandwich Wall Panels in the New German Federal States

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Summary

Three-layered external sandwich walls in the new german federal states were found to frequently exhibit damages which influence the durability of these walls and consequently their stability. In order to increase the remaining service life of the large panel buildings, specific rehabilitation measures are necessary. Examinations have proven, that an adequate measure is the application of a thermal insulation system on the outer walls. The stability of the weather exposed layers of the sandwich panels is found to be given, before and after the application of such a measure.

1. Problem

Three-layered external sandwich walls (Fig. 1) in the new german federal states were found to frequently exhibit the following typical damages: Cracks in the outer weather-exposed facings, varying thickness of the outer facing, insufficient concrete cover, high scattering of concrete strength, powdering surfaces, thermal bridges and permeable joints.

In addition, doubts are often being raised, whether the steel anchors between the outer facing and the structural concrete are indeed, made of stainless steel and whether these anchors were installed according to the plans and in sufficient number.

Within the scope of the rehabilitation works on the external sandwich wall panels, which have to be carried out in order to retain the large panel buildings, following questions had to be resolved:

- Can the existing external wall constructions be regarded as being sufficiently safe?
- Are additional anchorages for the outer facing layer necessary?
- What measures are indicated in repairing the external walls in terms of adequate thermal protection, crack formation, corrosion and permeable joints?

- Will the stability be retained once additional thermal insulation measures are applied on the external weather exposed layers?
- Can the dowels required for attaching the thermal insulation systems be anchored exclusively in the outer layers?

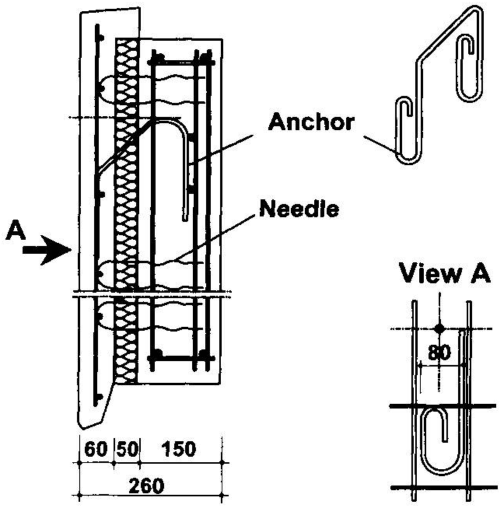

Fig. 1: Structure of the external wall - type WBS 70 in cross section

2. Investigation

In the paper methods for determination of the actual in-situ condition, possibilities of rehabilitation measures and methods for assessing the stability of outer facings and their anchorages are described.

3. Results

Investigations into the load bearing behaviour of three-layered external wall elements (sandwich panels) of large panel buildings in the new german federal states, yielded the following results:

- The stresses imposed on the weather-exposed layer from the relevant loading cases are low.
- The stability of the load bearing anchors was verified under the relevant cases of loading before and after anchoring the thermal insulatuion system in the outer layer.
- A subsequent installation of thermal insulation systems to the weather-exposed layer reduces the action on the load bearing anchors, as this reduces the relevant load case temperature.
- The typical cracks in the weather-exposed layers that mainly occurred during manufacture of the walls pose no danger to the stability of the load bearing anchors.
- The fatigue strength of the stainless steel load bearing anchors subject to thermal cyclic loading is ensured.
- The thermal insulation system is to be fixed to the weather-exposed layer only.
- Application of a suitable subsequent thermal insulation to the weather-exposed layer would stop a possibly already beginning corrosion.

Repair of Concrete Sandwich Walls Fasteners and Layers in Residential Buildings

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Zbigniew Scislewski, born in 1936, graduated from the Civil Engineering Faculty of Warsaw Technical University in 1958. He currently has professor positions in the Building Research Institute and of Warsaw Technical University.

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Michal Wójtowicz, born in 1948, graduated from the Water Engineering Faculty of Warsaw Technical University in 1972. He currently is a head of the Protection of Metal Constructions Laboratory in the Department of Durability and Corrosion Protection.

Summary

Sandwich walls have found a wide range of applications in constructing residential buildings in Poland. Investigations show that there are a lot of imperfections in fixings of elevation layers in existing buildings. They come from manufacture reasons, for the most part consisting of using non-stainless steel for production of fixings. This may result in decreasing the durability of fixings but also in lowering the safety level of inhabitants. The method of checking the fixings as well as the way of repairing buildings has been elaborated.

Keywords: durability, walls, concrete, reinforcement, fixings, wall insulation, repairs, residential buildings.

Construction of residential buildings from prefabricated units has been started in Poland in sixties. It was planned that the buildings would last for 70 years. Buildings of this type are currently used for 20 to 30 years and one can expect an advancement of the degradation of building units. Experience shows that plenty of defects occur which can significantly affect the durability of the buildings, especially those generated in stage of construction of objects and during production of units.
The sandwich wall units used in Poland are composed from the following layers:

- facade reinforced concrete slab,
- heat insulation layer,
- internal reinforced concrete construction slab.

Observations and investigations have shown that the most important threat for walls is abnormality in the coupling between the facade concrete layer of the wall and the construction slab. The Building Research Institute has performed investigations of sandwich units used in residential buildings in different parts of the country for the last 11 years. It was decided that investigated buildings ought to be erected before 1984, because up to that time the production of the units was very high and in the same time there was shortage of building materials and supervision over all type of work was insufficient. At least over 500 wall plates were investigated.

The condition of the concrete of facade plates mostly exposed to interaction of climate agents was sufficient in 90% of the cases. They were made from good quality concrete. No corrosion effects of reinforcement meshes and anchor bars were found. Measurements of the carbonisation rate shows that in the next 50 years corrosion should not occur. Only in 10% of the cases low concrete quality or non-adherence to the requirements with respect to heat insulation thickness were found.

The most important threat for the slabs comes from steel fixings. It was stated that:

- The thickness of facade slabs was overextended in comparison with the designed one (on average by 8 mm), while the thickness of mineral wool layer was simultaneously lowered.
- Incorrect positions of hangers in comparison with design requirements were found in 80% of the cases.
- Incorrect anchoring of fixings in facade layers (absence of anchor bars or too low diameters of bars) in occurred in 60% of the cases.
- Only in 10% of the cases the quality of steel was consistent with requirements. Ordinary steel of the St3SX, St3SY, St0 type or stainless steels, which were incorrect for this purpose, considering their brittleness were used most frequently.
- Despite of the fact that considering it's corrosion resistance incorrect steel was used, no threats coming from steel corrosion were found.
- In half o the investigated cases concrete bridges between internal and outer slabs were found.

Unfavourable symptoms in the buildings were freezing of walls and cracked facade walls.

The necessity of saving energy caused a change of the insulation requirements for buildings. One of the results was improving the insulation of outer walls. All the partitions made before 1982 do not adhere to the current requirements.

Repair of facade layer consists on making strong and permanent connection with the construction layer. In most cases it consists on introducing additional connectors. All connectors should be made of steel resistant to corrosion.

1. The most important problem of durability of outer sandwich walls in Poland is related to the efficiency of fixing the facade slab to the construction slab. No defects of concrete and reinforcement were observed in the facade plate.
2. Despite using connectors made of steel not resistant to corrosion there was no significant threat caused by the development of corrosion. However incorrectness of performing of the units and use of not appropriate materials causes that violation of adherence is possible.
3. In the case of wall insulation it is necessary to check the state of fixings and in the case of abnormality, additional connectors should be used.
4. Investigating the state of anchoring is very arduous and employing of non-destructive methods is limited due to small spacing of steel bars and use of stainless steel. For this reason it is necessary to continue looking for less labour consuming methods for checking the state of the anchors.

Refurbishment of Buildings with Back Ventilated Rainscreen Cladding

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Summary

In many European countries—particularly in Eastern Europe—large-scale housing developments form the mainstay of the housing economy. On the one hand, these large-scale developments guarantee affordable housing; on the other hand, however, they also represent a factor of social uncertainty for their residents. The objective must therefore be to attractively design this living space and its surroundings so that the residents can identify themselves with it. An important feature of a housing complex with which people identify is the facade. Its design, together with the structural comfort that it offers its residents, can be decisive for an individual's positive identification with the building.

1. Introduction

The majority of these large-scale housing developments were built using industrially prefabricated materials. In many cases, the quality of these materials and the construction work were unsatisfactory. Damage caused by moisture and corrosion is only one of the consequences. Thus, improvement of the outside appearance is only one aspect of the refurbishment of such facades. The system of back ventilated rainscreen cladding ensures that the structure dries out within the shortest time possible. Advancing carbonisation is halted, and the required airtightness is created. The use of chemicals for protection against corrosion can be avoided. Mineral insulation, which can be applied in any desired thickness, reduces heating costs and ensures the well being of a building's residents. Uneven surfaces on the outer wall are bridged over, thus creating a vertical line. Non-back ventilated cladding systems cannot fulfil these structural requirements. Back ventilated rainscreen cladding ensures the expected remaining life of the refurbished building to its full extent.

2. Function of Back Ventilated Rainscreen Cladding

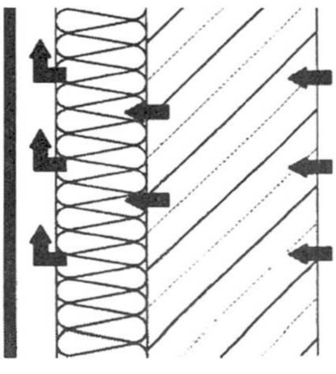

Fig. 1 Schematic representation of back ventilated rainscreen cladding

The back ventilated rainscreen cladding system essentially consists of four components: The supporting framework, the thermal insulation, the back ventilation, and the protection against weather (cladding). The functions "protection against loss of heat" and "protection against weather" are constructionally separate components. Moisture inside the building is drawn through the absolutely vapour permeable thermal insulation into the adequately dimensioned back ventilation area. The non-constrained supporting framework, usually made of aluminium, surrounds the building and ensures the required wall clearance. The actual protection against weather is provided by the cladding, which is available in a large variety of materials and designs.

3. System Components

Back ventilated rainscreen cladding consists of a series of integrated system components which—regarding their application in Germany—either conform to industrial standards or construction codes.

Anchoring devices are a combination of plugs and screws, which anchor the wall support of the supporting framework into the anchoring foundation. Cadmium plated screws are admissible if they have been proven to be adequately protected against corrosion. It is also possible to use stainless steel or grout anchors, independent of the anchoring foundation. Anchoring devices must conform to general construction codes; furthermore, they must be selected according to their suitability for use with a particular anchoring foundation and the calculated load they are expected to bear.

Connecting devices are generally screws or rivets, which connect the individual components of the supporting framework. Connecting devices must possess proof that their dimensioning meets the requirements set on them. These requirements must also be met when using supporting frameworks made of wood.

Fastening devices are the mostly visible parts that permanently fix the cladding to the supporting framework, whereby a principle difference is made between visible and hidden fasteners.
Visible fasteners are e.g. screws or rivets, which are arranged on the surface of the cladding panel. For so-called small-format cladding panels, nails, screws, clevis hooks and driven-in hooks can also be used.
Hidden fasteners, e.g. undercut anchors and welded bolts, are attached to the back of the cladding panels.
It needs to be mentioned here that the choice of fastening device can have considerable influence on the appearance of the facade after it has been installed. Visible fasteners are generally less expensive than hidden fasteners. In addition, fastening devices are often not only system-dependent, but also dependent on the supporting framework and the choice of cladding.

Supporting frameworks are the constructional connecting member between the anchoring foundation and the cladding.
The supporting framework is stably attached to the building, absorbs all loads occurring as a result of wind suction and wind pressure and transfers these to the structure. At the same time, the supporting framework absorbs any strain caused by fluctuations in temperature. The choice of supporting framework components is determined by the cladding, the desired type of joint, the expected weights, and the anchoring foundation.
The supporting framework's construction consists of wall angles and vertical supporting profiles. Depending on the cladding, horizontally arranged profiles are also sometimes possible. The structurally formed "fixed point" is meant to transfer loads arising from wind suction and wind pressure as well as the calculated construction load onto the building. "Movable points" merely absorb wind suction and wind pressure forces and accordingly, they are more weakly dimensioned.

Ventilated Cavity Façade System with Pre-painted Aluminium Sheet

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Summary

For 30 years ventilated cavity façade systems have been widely used for renovation as well as new façade claddings. This system has proved to be optimal in many aspects due to its „natural" function. While many outside façade cladding materials could be applied, pre-painted aluminium sheet have been preferred by many architects and planners. This material offers corrosion resistance, beauty by its choice of many colours, and functionality at a reasonable price. Especially for residential building renovations the overall system, which is including insulation material, is a special choice with high future market potential.

Keywords: Ventilated cavity façade system, rain-screen façade, chimney effect, breathing façade, coil-coating process, marine quality aluminium alloy, permissible load, PVdF paint (polyvinylidenfluorid), cassette-type panels, stiffeners, honeycomb panels, sound-deadened aluminium.

By consequentially separating the weathered surface of a façade from the insulation and the construction material of the wall allowing for an airflow between the weather shield outside and the insulation behind we achieve the so-called „rain-screen façade" or also called „ventilated cavity façade system". This system is a so-called „breathing" façade. It is as natural as can be and therefore represents an optimum in technology which only has to be coupled with the proper materials chosen for the purpose in respect of corrosion resistance, optical appeal, choice of colours, maintenance, etc., also in relation to its price.

The principle is as simple as can be as everybody agrees that insulation saves energy ford air conditioning as well as for heating and therefore saves costs in the lifespan of every building. The air cushion between the outside cover sheet (which can be done in a wide range of materials starting from fibre cement to ceramics, to steel panels or aluminium sheet and the insulation material) is the best and cheapest insulation anyway.
In case of rain the ventilated cavity façade system rejects water infiltration which may damage the insulation material. Usually an open joint system leads to counter pressure so that the humidity infiltration is negligible. Any humidity or moisture still prevailing will be taken out in

due time by the constant flow of air (air circulation) which then leads to the so-called „breathing" façade.

The ventilated cavity system takes into consideration prevailing temperatures, humidity, comfortable room temperatures, etc. By choosing the proper outside cover material longevity of the façade will be determined designed also to withstand all climatic and environmental conditions. When using only weather-resistant, corrosion-resistant and fire-resistant materials this results in a mature system which has proved to be suitable for renovation as well as new building claddings for approx. 30 years in many countries of the world.

Due to the ventilation of the air according to the „chimney effect", the result of this system is a very comfortable room climate. No matter which climatic conditions - if extremely hot or cold, wet or dry - the breathing façade is physically the best solution as it is a natural principle.

The major arguments for any ventilated cavity system are:

1. The total construction is completely weather-resistant. The façade cladding increases the longevity of the building.
2. The consequential separation of the weather protective outside material (e.g. aluminium sheet) from the insulation material protects the building against weathering.
3. The air circulation avoids heat stagnation and humidity damage.
4. The construction walls and also the insulation material stay dry and fully functional.
5. The total construction is open for humidity diffusion.
6. The construction of heat bridges is avoided.
7. The insulation material secures the greatest possible heat conservation respectively cooling inside the building.
8. A comfortable room climate is the result.
9. Heat losses in winter as well as heating up during summer is avoided.
10. The rain-screen ventilated cavity façade protects the building components against strong temperature stresses.

Furthermore, maintenance is extremely low. The so-called „breathing façade" also gives an excellent noise reduction - as every thickness and/or density of insulation material - be it rockwool or glasswool - is possible.

Also, this system allows for absorption of building tolerances. By different colours, sizes, designs, etc., individual architectural aspects can be considered.

In case of damage, repairs can be done comparatively easy and cost-effective. The installation is independent of any weather conditions.

While, as an outside skin of this system, many materials can be chosen from we would like to focus on pre-painted aluminium sheet as one major option. For about 30 years pre-painted aluminium sheet have proven to be very suitable for this system. In one practical case, for example, a special corrosion-resistant marine quality aluminium alloy AlMg3 (AA 5754) has been chosen. Due to special rolling technology and annealing, the mechanical value of this material has been optimised to 96 N/mm2 as permissible load according to DIN 4113. This German standard is even demanding security factors of 2.5 in order to be on the safe side.

The surface of the aluminium rolled product is continuously degreased and chromated in a so-called coil-coating process before a primer coat is applied and cured as well as a topcoat on top. Depending on colours and qualities, 2-coat / 2-bake up to 4-coat / 4-bake systems can be applied. The coil-coating process is designed for an optimal flatness achieved by tension-levelling.

Fastening Systems for Suspended Rear Ventilated Facades

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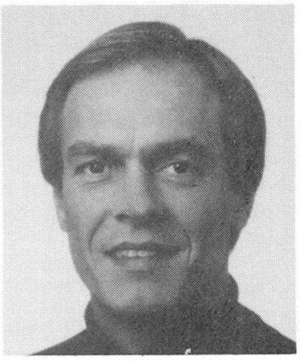

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Summary

The suspended rear ventilated facade in conjunction with appropriate insulation and supporting structure systems jointly offer optimal protection, preservation and embellishment for any building even in difficult situations.
Fascinating and original architectural effects can be obtained by utilising widely varying cladding material, surface structures, colours, formats, patterns, joint designs, structural sections and and manifold attachment systems.

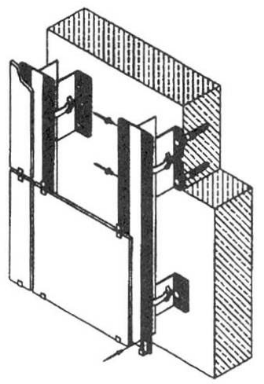
1. Rear ventilated facade

On new buildings as well as on existing buildings (maintenance, preservation and embellishment) the suspended rear ventilated facade system is the system that fulfills all the physical construction and design requirements for a facade: it insulates the structure from cold, heat and precipitation, it protects and decorates the building, it provides a comfortable environment inside the building, it saves heating energy costs, it permits diffusion of moisture.
Consequently the market offers a wide range of substructures for the different panel materials and systems with visible or hidden attachment.
In conjunction with a sophisticated anchoring the planner and architect is given a complete range of tools in order to give each facade an individually styled look.

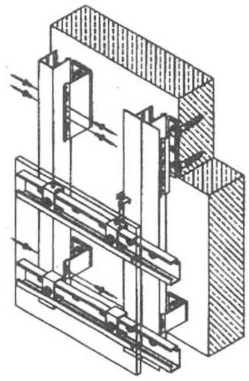
2. Substructure principal and aspects to be considered

There are two categories of substructures (see fig. 1,2).
While the design of new buildings and their facades may be done using standard substructures, the cladding of existing buildings must be planned by taking into consideration the situation and the details of each individual building:

- additional weight from heavier facades (foundations, etc.)
- nature of the foundation for anchors (pull-tests with plugs may be necessary)
- walls may be uneven or have a strongly segmented strucure (see fig. 3).
- defective zones (anchoring in certain areas impossible or too costly)
- with sandwich panels (three-layer construction): does it make sense and can the anchoring be attached to the outer cladding or should it be to the load-bearing layer ?)
- anchoring in the joint zones, corner zones (see fig. 4), etc.

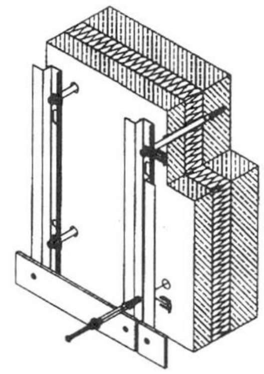


a) Excentric anchoring

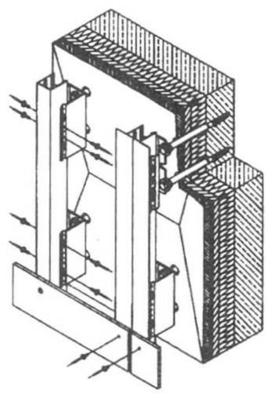


b) Centric anchoring

Fig. 1: Systems with brackets



a) Fixing with distance wallplugs



b) Fixing with distance wallplugs and brackets

Fig. 2: Distance systems

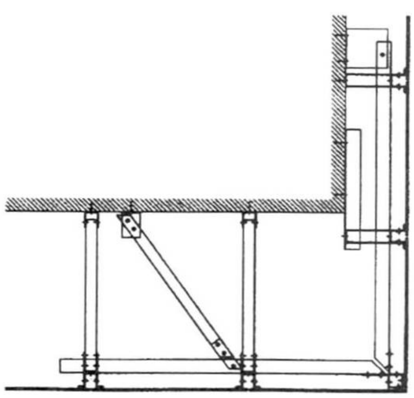


Fig. 3: Example: distance up to 700 mm

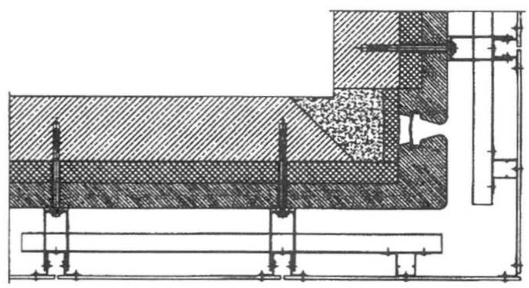


Fig. 4: outer corner WBS 70

Retrofitting of Residential Prefabricated Buildings in Hungary

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Summary

The specific structural model of Panel-System buildings is presented highlighting the importance of the inhomogeneities occurring between the different types of concrete like high strength cured panel bodies and in situ cast fresh fillings with partial local reinforcement. The elasticity and the deformation behaviour is significantly different in the panel bodies and in the joints. So the answer of the composite structure is very much different from the expected results gained from the common structural model of homogeneous (perforated) discs. This behaviour causes important stresses in some zones in the buildings with 10 or more storeys even in case of standard design wind speed. The realistic and necessary life span of about 100 years requires some extra load-bearing reserves also for extra impacts like fire, limited seismicity, etc. The large number of such houses underlines the necessity of clear knowledge of the real structural conditions.

Keywords: Panel-system buildings, inhomogeneity, joints, compatible deformations, shrinkage, horizontal loads, load-sharing, temperature-differences, load-bearing, life-span.

1. Description of the Panel-System Housing in Hungary

The centrally financed wide-range housing with panel-system was representative in Hungary between 1960 and 1980, like in many other Central-European countries. The peak production capacity exceeded 2 Million sqm flat area per year in approx 15 plants located in the major cities of Hungary. Such sudden growth of housing was not possible with traditional technologies. The panel-system housing also ensured the reduction of the required working capacities at the site and led to an overall reduction of the specific working hour demand per flat-sqm. These houses were installed with slightly higher standard than before but the durability of the furnishing elements was not sufficient. So partial modernisation is more and more required by the users. This demand even increases because of the change in social needs. At many houses there is a significant shortage in the thermal insulation parameters too, underlined by the recent rising energy prices. By now approximately 15% of the national stock of flats consists of panel-system houses. Since it is not possible to replace them within a short time the modernisation and the proper maintenance of these buildings has high importance. On the other hand there is practically no way to dismantle them economically taking into consideration the high energy demand and the problems of the disposal of resulting debris. So the only possible strategy should be the retrofitting and the planned operation for long life-span of these buildings. The long life-span causes higher pricing of the load-bearing components and the need of clear sight of the real structural behaviour.

2. Specific Structural Character of the Multi-Storey Panel-System Houses

The most important reasons which make unusual the structural behaviour of these houses come from the construction technology itself. The large size panel elements are prefabricated so they obviously must have rather high strength just for the needs of the early transportation and storage. Their controlled, „factory made" concrete with proper water/cement ratio and accurate compacting produces high quality and high deformation modulus. The dominant part of their shrinkage takes place before the erection of the house. Later at the site poorer and often over-watered, not properly compacted concrete is poured into the „3-D network" of the joints to connect the panels. This site work is difficult and the quality control has much worse chances. So the void ratio in the concrete of the joint can reach even 25 or 30%. Based on these conditions its shrinkage ratio is about 0.5 to 1.0 $^0/_{00}$, its elasticity modulus and ultimate stress is much less than those of the high strength concrete of the panels, and the creep effect also takes place even under small stresses. At the same time the rest of the shrinkage occurring in the panel after the erection is only about 0.1 $^0/_{00}$. The concrete of the joints starts its life only when the panels are already „matured and shrunk". So the cracks of shrinkage definitely develop in the concrete of the joints and at the contact surfaces with the panels just in the very first weeks of the life of the house. In this way the strong and rigid panels of good quality are connected to each other by rather weak and cracked, heavily shrunk joint-concrete zones. This situation forms really the definite conditions of the inhomogeneity. Unfortunately the researchers and designers who are not very familiar with the construction technology often neglect the site conditions causing serious inhomogeneities. The real proofing of all these aspects may come only by costly and complicated large scale tests and measurement series. Such tests in Hungary in 1980-81 proofed the behaviour being different from a homogeneous model. Here the improper level of joint working between the neighbouring wall elements was detected together with the high deformations of the vertical joints. Also was proofed the overloading and cracking of the trimming zones. It is important to mention that only about 60-70% of the loads/stresses come from the permanent/dead load at a 10 storey building. The rest is caused by alternating effects (winds, etc.). The really developed stresses/deformations in several zones can exceed the correct limit of reversible (elastic) deformations. The repeated effect of non fully elastic deformations seriously influences the life-span of the structure. The computation method with all of its details and practical simplifications was developed gradually within a longer time with a permanent interaction of site control. The rigid and high grade indeterminate composite structure has also an important side effect of extra loads caused by the temperature-differences between the elements of the facade and the internal ones. The panel building is rather sensitive to the differences of sedimentation as it was proofed by the model experiments too.

3. Behaviour of the Inhomogeneous Structure Derived by the Ultimate Deformation Mechanism of the Concrete

One of the most important problems of joint working occurs in the vertical joints. Here the „storey-high" (approx. 3 m long) beam of joint-body develops more than 1 mm of accumulated longitudinal shrinkage. Because of this the body of the joint is separated/broken into parts. When shear-type vertical connecting forces intend to develop between the panels to be connected - they can not be transmitted until a higher deformation of the panels will not close these cracks. These necessary higher deformations of the wall-panels develop at 10-storey (or higher) buildings by the usual vertical (structural + wind-caused) loads/stresses but the concrete of the joint has furthermore lower deformation modulus and ultimate strength which are both limiting the transmittable forces. Similar connection problems were proofed in horizontal joints by large scale laboratory tests between 1980 and 81 in Hungary.

Sandwich-Systems in Poland in the Years 1970–1985

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Summary :

In the report, the division of sandwich-panel houses in Poland after the year 1970 becomes, with the characteristic of the material- and construction solutions, declared. At that residences, that were handed over in the years 1970 - 1985, anomalies and technological mistakes appeared. This makes at these days a redevelopment of approximately 60 million m² facade screens by eliminating leaky positions and frost damages necessary by means of insulation. Out of consideration for the technical condition of the sandwich-panels, about 30 million m² should be secured before insulated.

Description of the panel-systems and their technological mistakes

Since the year 1970 the increase of the flat-housing in Poland leans on the industrial technology, mainly on the panel-sandwich-constructions. The construction of the panel-systems based on big reeinforced steel-concrete-slabs in the screen of 60x60 cm as well as 60x120 cm. The material-solution was virtually standardized, that means

- the prefabricated parts were manufactured from concrete of the class B20, and
- in the joints on-site concrete of at least the class B15 was used.

The prefabricated parts became reeinforced with steel-fences from 34GS and 18G2 as well as St0 and St0S. The concrete-stacking of the outside-walls were connected until 1983 with help of anchors from usual steel as St0S or St3SCU. Only after the year 1983 stainless steel for example H13N4G9 was used.

In the single panel-systems different solutions for outside-walls existing, but they have a common characteristic in

- the interior concrete-wall (bearing)
- the external concret-wall (rain-screen) and
- the insulation lying between from polystyrene or mineral-wool of the thickness 60 mm, after the year 1982 even 120 mm.

The rain-screen and the internal (bearing) wall were connected with steel anchors. From the start the anchors were made from usual steel-types like St0 or St3SCu with a corrosion-protection-layer. First in the year 1983, the standard BN-79/8812-01 and the catalogue of the company METALPLAST specified the use of solid stainless-steel for the anchors. They should be manufactured from corrosion-constant materials with a comparable lifespan as the total outside-wall-element.

The technological mistakes of the outside-walls were caused by the unreasonable quality of the used materials and the not competent production. After the year 1980, the negative appearances were added by the leakages in the joints and windows, just as frost- damages caused by thermal-bridging.

The observation and examination of the ITB shows, that the anchors of the outside-walls show a row of mistakes, which also influence the constancy and stability of the panel-constructions. To the determined mistakes of the anchors belong

- the use of not to the standard corresponding steel-sorts,
- the lacking bracing in the rain-screen,
- the too thin layer of the corrosion-protection and from it following cracks in the rain screen,
- the visuable corrosion of the anchors in the area of the insulation.

Redevelopment of panel-constructions

The in the years 1980–1990 enforced redevelopments of the slab-constructions, existed predominantly in the removement of the frost damages and leaks, mainly by insulation. The endangering by the corrosioned anchors in the sandwich-panels of not redeveloped houses still remains as a problem. An additional insulation could decrease the corrosion of the anchors considerably.

Summary and proposals

At the in the years 1970-85 completed slab-constructions approximately 30 Mill m^2 surface of the outside-walls remains for redevelopment by insulating (render-systems or ventilated systems).

Not regulated remains the judgement of the condition of the connections (anchors) between the rain-screen (external wall) and the bearing wall (internal) in the sandwich-panels. The problem necessitates a complex editing of test-procedures for the anchors and possibly also administrative decisions.

Presently the rain-screens of the sandwich-panels will not be secured before insulating, although there are admitted systems with the segment-anchors of the type SLR and the EJOT Wetter-Schalen-Sicherung WSS.

Analysis and Repair of Damages in Precast Reinforced Concrete Panels

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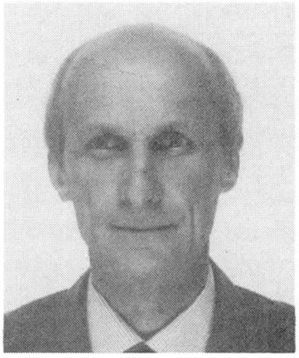

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Summary

The long-term viscoelastic analysis of exterior precast concrete panels subjected to shrinkage and temperature induced strains is discussed. The exterior stratum of the panels is assumed viscoelastically restrained and a general approach for sectional and structural analysis is developed. The obtained results point out that cracking limit state can be attained with great probability so that repairing works often become necessary. The basic aspects of the service behaviour of these particular structures, discussed in a worked example, allow to feasibly define the prerequisites of the rehabilitation works.

Keywords: Shrinkage, temperature, creep, panels, thermal strain, tensile strength.

1. Introduction

A great number of precast buildings with structural arrangements consisting of R.C. bearing panels has been erected in Eastern Europe in the years 1960-1980. These buildings have been subjected to various degrading phenomena, especially regarding the exterior walls for which panels consisting of an internal bearing stratum and of an external thin one have been employed. The restraint degree between these two parts varies in a quite general way, so we can observe panels with the two parts free to exhibit relative displacements or panels for which relative movements are partially or rigidly prevented. Three typical connections illustrating these concepts are shown in Fig. 1. As a consequence of the restraining degree a marked statical interaction between the two strata can arise when imposed deformations are present. This can produce cracking phenomena to which a reduction of the structural life-time is related.
The rehabilitation of precast exterior walls requires to repair cracks and to reduce the intensity of the imposed deformations, in particular the ones due to temperature variation. In fact, owing to the significant age of the panels shrinkage has nearly reached its asymptotical value so no further increments of this imposed deformation have to be expected in the repaired structures. An efficient and economical rehabilitation technique consists in injecting the cracks by means of epoxy resin and in applying on the exterior surface an insulation stratum in order to reduce the temperature effects. The design of these repairing devices requires a reliable analysis of the state of stress produced in the external stratum of the wall by time variable imposed deformations, taking into account their interaction with concrete creep. This in order to correctly evaluate the final tensile stresses in concrete and to reliably proceed in assessing structural safety for cracking limit state.

2. Long-term stress analysis of precast exterior walls

Referring to Fig. 2, the external stratum of a precast exterior wall can be represented by a beam element viscoelastically restrained at its end and subjected to the imposed deformations due to shrinkage and temperature. According to Fig. 3, we assume that the shrinkage deformation $\bar{\varepsilon}_1$ is uniformly distributed along the depth of the stratum while temperature can be considered to be distributed according to a parabola with extreme values $\bar{\varepsilon}_2$, $\bar{\varepsilon}_3$.
The time variation of shrinkage is monotonically increasing while for temperature we can assume a time sinusoidal distribution with period θ=1 year. In this way we can subdivide the imposed deformations into three partial deformations, namely : a constant deformation $\bar{\varepsilon}_1$ monotonically increasing in time produced by shrinkage ; a constant deformation $\bar{\varepsilon}_2$ and a parabolic deformation $\bar{\varepsilon}_3 - \bar{\varepsilon}_2$ due to temperature with a time sinusoidal distribution. The deformations $\bar{\varepsilon}_1$, $\bar{\varepsilon}_2$ do not produce sectional stresses as they are distributed according to the Bernoulli-Navier hypothesis. The stresses connected to them are only the ones produced by the end restraints. On the contrary the deformation $\bar{\varepsilon}_3 - \bar{\varepsilon}_2$ generates sectional stresses which have to be added to the ones produced by external restraints. In Fig.4 the developing in time of the total stress at the superior edge of the section, calculated according to a viscoelastic analysis is reported. Creep reduces the stresses which lie at the interior of the two extreme lines 1-2 respectively depending on the surrounding temperature existing when the wall was erected. In particular to a high surrounding temperature only a wall shortening in time can be consequent so that temperature effects will have the same sign of the ones due to shrinkage, represented by line 3, and the total tensile stresses reach their maximum value (line 1 of Fig. 4). On the contrary a low surrounding temperature forces the wall only to increase its length consequently the total stress is minimized (line 2 of Fig. 4). For an intermediate temperature of erection the total stress varies according to line 4. After injecting the cracks only temperature effects produce tensile stresses in concrete as shrinkage deformations can be assumed totally exhausted. In this way indicating by f_{ctm} the mean strength of concrete and by $\sigma_{ct}(\bar{\varepsilon}_2, \bar{\varepsilon}_3)$ the tensile stress produced by temperature, the cracking limit state can be assessed imposing that $f_{ctm} \geq \sigma_{ct}$. As σ_{ct} depends linearly on $\bar{\varepsilon}_2$, $\bar{\varepsilon}_3$ the preceding inequality enables us to define the maximum temperature strain compatible with an uncracked state of the panel and the prerequisites of the insulating stratum which has to be placed on the external surface of the panel.

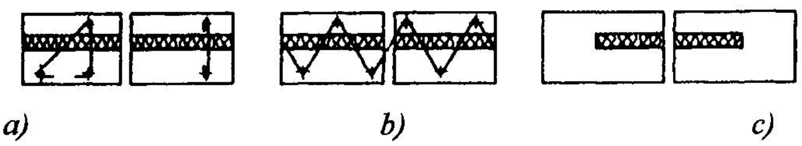

Fig. 1 Types of restraint : a) free b) partial c) rigid

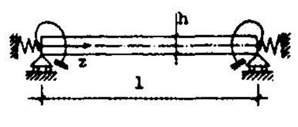

Fig. 2 Structural scheme of the external stratum

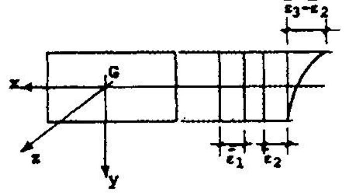

Fig. 3 Strain distribution

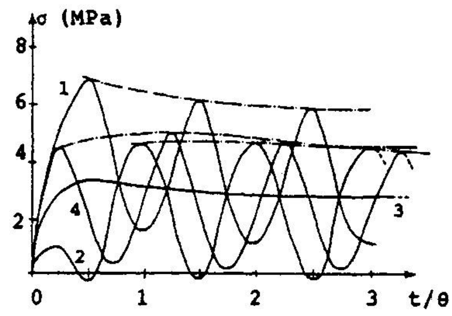

Fig.4 Total stress diagram

Self-Supporting Structures for the Restoration of Balconies

Eberhard MÜSSIG
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Eberhard Müssig, born 1948. He graduated in 1971 from the Technical College in Munich following an apprenticeship in metal-working. He has been owner and managing director of the company of Wilhelm Müssig GmbH since 1972.

It was usual many years ago that balconies were planned by the architect on an individual basis and - depending on the requirements - were always built by craftsmen as a unique construction.

Now it is appropriate to systematize such solutions for recurring building jobs of known applications.

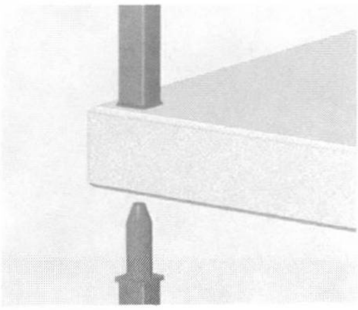
Planning, production and assembly shall be speeded up and simplified by this, and the quality thereby improved.

In extreme cases, all components are identical and need only the predicted basic conditions of the building structure. In this case, the difference is then only in the addition and the color applied. The predictions of stability can, as a rule in such cases, be made by a static analysis of the structure type.

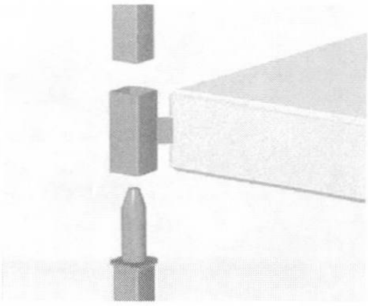
This is the development we had in recent years in the field of prefabricated balconies.

During the course of the many discussions with planning architects and the considerations made by the author in many areas of resolved building-problem definitions, the author has come to the conclusion that just about every specification is one requirement too many and he is therefore of the opinion that a liberation is needed from the rigid framework of general specifications.
It is for this reason that he is pursuing a course in a different direction. It is not the product that is being brought into a system, but rather the types of connections and the operating processes that shall be systematized.

Two examples for this are given here:

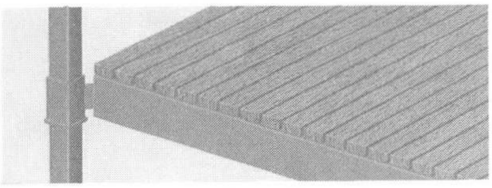


Projecting insertion socket

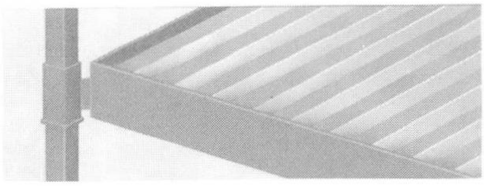


Flush insertion socket

Here two examples in the designs available for balcony floor surfaces:



*Balcony floor surface, Type 2:
Frame with wooden planks (spruce), steam-pressure impregnated.
Projecting insertion socket*



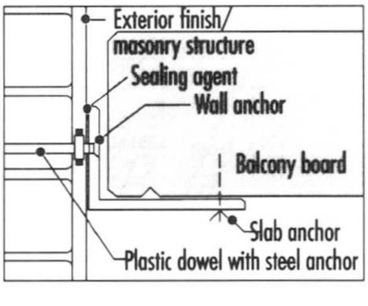
*Balcony floor surface, Type 4:
Frame with trapezoidal-corrugated sheet surface for screed-concrete placed at the building site. Projecting insertion socket*

The basic conditions for the structural supports are defined by the insertion connections. The choice of cross-section can be defined according to the planner's wishes or in compliance with requirements for the demonstration of weight-carrying sureness. Slenderness and optimum use of materials are endeavored at all times.

To this end, a static analysis report that is easy to read shall be prepared end so as not to incur any disadvantages in comparison with a type design analysis for the time required to obtain approval. The advantages of an up-to-date static report are the freedom in the dimensions possible, as well as the general applicability of the report.

Mounting fixtures are required on the wall as a rule, since even the smallest fluctuations render these objectively useless for free-standing, stable balconies arranged above one another. The wall mount is always an individual adaptation of its entity: From the masonry structure in Hamburg to the timber-framework construction in Stuttgart. Yet even this adaptation can be included in the operating processes in the system. As such, a CAD program has been developed in recent years which includes the known types of wall structures that can be combined with those approved fastening techniques available as well as the static and dynamic forces calculated for these.

Example of a side mounting on the building:



A straightforward mounting to the side of the building is possible according to the static analysis - depending on the locally prevailing conditions.

As well as the protection against falls, the railings also constitute a part of the balcony that determines the optical outward appearance to a great extent. The author is convinced that a railing system has to be of modular construction, that is to say, the handrails, the posts and the panel elements shall be chosen as desired from a large selection available, and that these can be combined at will.

A balcony system must be of sufficient openness so that the architect's designs can be joined using existing system components without any difficulties. For the author, a system product means that it can be fabricated and mounted to meet the customer's requirements without any intervention to modify systematized operating processes. By permanent criticism at the source of Müssig products, the author hopes to bring about a continued increase in the diversity of the system, and hence to allow greater freedom in planning.

Exemplary are the constructions from the French engineer Gustave Eiffel, as to how few standardized construction components are needed, these being namely rivet and rod, to cover the spectrum of construction tasks from the bridge to the dome to the famous tower, that have been resolved in the interim.