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Strengthening of Building Structures with FRP-Fabrics

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Summary

There is great potential and considerable economic advantages in strengthening existing concrete members with epoxy-bonded composite plates. Composite fabrics and a unidirectional tape can also be used. This paper presents and discusses briefly the use of CFRP (Carbon Fibre Reinforced Polymers) for strengthening concrete structures. A historical background is presented as well as some results from tests on beams strengthened for shear with composite fabrics.

1 General Concept for strengthening and testing

If it is considered the amount of money that are fixed in the existing buildings and infrastructure there are in many situations economically attractive to repair the structure and extend its life. However, it must be considered as a great challenge, to repair and upgrade the transportation infrastructure of the Western world. There are several methods for repairing or strengthening a structure. One such method that has been used quite extensively around the world in the last two decades is steel plate bonding, i.e. when steel plates are epoxy-bonded to the surface of a structure. At Luleå University of Technology, Sweden, research has been carried out in the area of plate bonding. The research work started in 1988 with steel plate bonding and is still continuing, but now with FRP (Fibre Reinforced Polymers) materials. These types of materials have the advantages of being very strong yet lightweight, and having excellent fatigue properties and outstanding corrosion resistance. In addition, composites are formable and can be shaped to any desired form and surface texture. The major disadvantage is that they are expensive (especially CFRP) while another disadvantage can be that the FRP-materials are anisotropic, i.e. they have different material properties in different directions. One very interesting and economic application of currently available advanced composite materials is the strengthening of damaged or structurally inadequate buildings and bridges. In this study three different applications methods were investigated; Hand lay-up, two different systems. System A and B; Pre-preg in combination with heat. System C; and Vacuum injection. System D. Material properties of the systems used are recorded in Table 1.

Table 1 Material data for CFRP-system tested

Property	System A	System B	System C	System D
Fibre system	Tape	Tape	Prepreg	Fabric [0/90°]
E_L, (GPa)	65.6	70.8	100.6	49.0
E_T, (GPa)	4.4	4.8	8.0	49.0
G_{LT}, (GPa)	0.7	1.0	4.1	3.1
ε_{LU}	0.017	0.014	0.014	0.013
σ_{LU}, (MPa)	1053.0	860.0	1450.0	577.0
σ_{TU}, (MPa)	9.6	24.6	29.0	577.0
t, (mm)	0.96	1.03	0.69	2.2
w, (%)	39	39	60	55

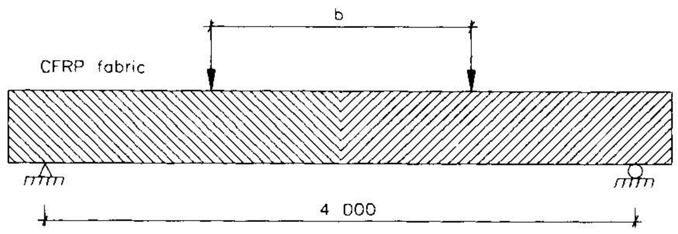

Fig. 1 Test specimens and test arrangement

A total of eight beams were tested, three beams were chosen to be reference beams, two of these beams, R1 and R2 now denoted SR1 and SR2, were strengthened after failure and loaded again. The dimension of the beams together with the test arrangement and the palcement of the CFRP fabric are shown in Fig. 1.

2 Application and test results

Before applying the composite some pre-treatment steps for the beams were necessary. First the beams were sandblasted. After this the surfaces were vacuum cleaned to remove loose particles and dust. For all systems, with the exception of System C, the pre-preg tape, a primer was applied to the concrete surface before the fibre system was applied. The temperature during application was 20 °C in all cases. All of the beams were strengthened with the CFRP-composite at a 45° angle to the horizontal plane.

Table 2 Test results from the four point bending test

Beam	System	b (mm)	Failure	F_{max} (kN)	δ_{max} (mm)	F_{test}/F_{ref}
R1	Reference,	800	Shear	212	10	1.0
R2	Reference,	1600	Shear	241	9	1.0
R3	Reference,	2000	Shear	226	9	1.0
S1	A	1600//2000	II	681//834	32//46	2.8//3.7
S2	C	1600	II/III	548	22	2.3
S3	D	1600	III	546	30	2.3
S4	B	1600	I	662	31	2.7
S5	B	1600//2000	II	695//839	34//39	2.9//3.7
SR1	B	800	III	390	22	1.8
SR2	B	1600	III	486	20	2.0

3 Summary and Conclusions

It is pleasant to present results from the tests performed which show a very good strengthening effect in shear with CFRP-composites bonded to the face of concrete beams. Three different application methods were investigated in the tests; hand lay-up (two systems), pre-preg with heat and vacuum injection. Compared with vacuum injection and pre-pregs, the hand lay-up systems were very easy to apply to concrete beams. Even if the composite has better material properties with injection or pre-preg, the results on site seem to be more controllable for the hand lay-up systems. Nevertheless, in special applications, e.g. with warm surroundings, pre-pregs can have a future since it would be possible to increase the glass transition temperature for the system. For the vacuum injection system, the biggest problem at failure was that the fibres buckled. It should be possible to overcome this with another type of weave. No measurable difference could be registered between the two hand lay-up systems used. Furthermore, it is very important that the condition of the existing structure be thoroughly investigated. Otherwise there is a risk that the failure mode for the structure can be changed, e.g. from a ductile bending failure to a brittle compressive failure.

Tests of Reinforced Concrete Strengthened with CFRP Plates

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Summary

This paper presents the results of the research carried out on five beams strengthened with CFRP plates (Sika CarboDur - System). The model of failure of the beams was discussed and compared with an examination of strains and loading capacity of a section. The last one based on the nonlinearity of concrete, reinforcing steel and linear relationships σ-ε of the CFRP plates and the glue was in accordance with an experimental test. The ifluence of plates bonded to the both vertical sides of the beam in a support region on a load-bearing capacity was firstly considered.

1. Introduction

The investigations presented below were carried out in order to provide with data for verifying the assumed analytical model concerning the bending and also to test the influence of additional carbon plates attached to side surfaces of the element in its support zones for anchorage conditions of the plates.

2. Experimental investigations of the beams strengthened with the plates

Five single-span beams (dimensions and loading scheme shown in fig.1) have been tested. CFRP plates were attached to properly cleaned beam surface with CFK-Sikadur-30 adhesive, recommendations of applying given by the producer of the strengthening system were precisell followed.

Basic information concerning the beams reinforcement and the mode of strengthening is presented in table 1.

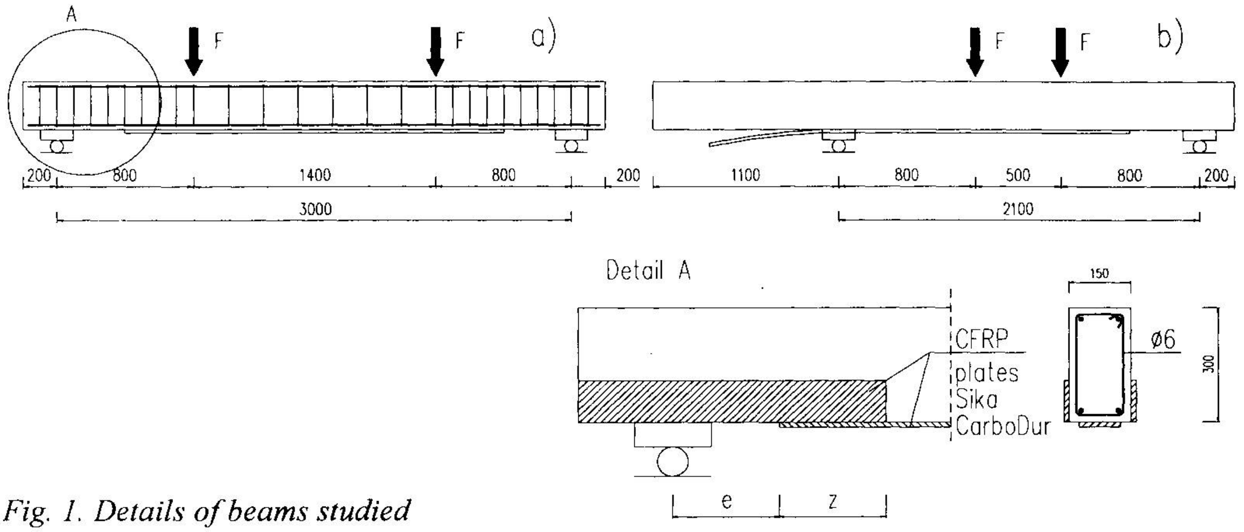

Fig. 1. Details of beams studied

Table 1. Details of test beams

Beam	Reinforcement ratio/bars	CFRP-plate (see Fig. 1)			Concrete strength[2)], MPa				Ultimate load 2F, kN
		type	e, mm	z, mm	$f_{c,cube}$	f_c	$f_{ct,sp}$	E_c	
B-04/S1	0.0039 2#10	S	150 300	-	33.8	28.4	2.8	23400	120 90
B-04/S2			150[1)]	-	51.3	36.6	3.2	29000	98
B-04/M		M	250	200 S and M	33.2	29.7	3.0	25000	120 (M) 120 (S)
B-06/S	0.0056 2#12	S	250 250	350 500	35.4	32.3	2.9	27400	140 145
B-08/S	0.0084 3#12	S	150	-	43.0	33.8	3.0	27300	180

1) half plate on both vertical sides of the beam
2) cubes 150×150×150mm, cylinders 150×300mm, E_c after DIN 1048

Conclusions

The investigations confirmed full cooperation within the pure bending zone of CFRP plate with the section strengthened in this manner. Thus it is reasonable to assume in the analysis the plane section principle. In the analysis as well material nonlinearity of the concrete and the tension stiffening pronciple were assumed. The proposal calculation model enables to evaluate the bending moment - curvature (or strain) relationship within the whole range of loading and thereby to estimate the value of cracking moment, reinforcement yielding moment and the ultimate moment resulted from limiting the strain of any of the materials in the section. It is also easy to estimate how much the load capacity of the plate may be used, if we know dimensions, the reinforcement ratio and material characteristics of the strengthening element.

Further investigations concerning anchorage zones of the plates are necessary. They are continued in Concrete Structures Department of Technical University in Lodz. Test on beams strengthened with CFRP plates and subjected to the cyclic load are foreseen to undertake soon.

Renovation of Facades and Masonry with Special Dry-Mix-Mortars

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Summary

The successful renovation of buildings with special dry-mix-mortars requires the exact knowledge of the conditions at the building generated by a competent analysis of the actual situation and an evaluation on the factors that caused the damage.
The right interpretation of the collected data will then result in the selection of special dry-mix-mortars. These materials must fulfil the requirements of high quality dry mix mortars according to technical properties, applicability, and quality assurance.

Keywords: Mortar, renovation, renovation render, damage analysis, joint-filling-mortar, stone-repair-mortar

1. Introduction

The maintenance and renovation of existing buildings are objects of common interest. The decay of buildings may be caused by ageing, increasing exposure to aggressive environmental factors, intensified exploitation and many others. The restoration of the damaged structures follows a wide spread area of different objectives. Whether it will be the structural repair on a road bridge in order to maintain infrastructure necessities, or the renovation of an ancient palace of high historical and cultural value. At a first glance the repair work at the different job sites make use of similar technical equipment and in many cases similar repair materials but going deeper into details it becomes clear that in most cases specialty products are required and applied. Before deciding on the right repair materials the object has to be analyzed in order to adjust the repair materials to the conditions at the job site and to maximize the success of the renovation operation. This paper will deal with some aspects on building condition analysis and the adjustment of special dry-mix mortars to minimize the risk of application failures.

2. Evaluation of the Building

2.1 Damage Analysis

The renovation of a building should include the removal of the circumstances that lead to the damage and the protection of the building. The first factor is therefore of present interest whereas the second one is future orientated. An all-including investigation plan should contain the documentation of the history of the building, the localisation of the damages and the analysis of the inherent factors causing the damages. This work builds the basis for the renovation plan which leads to the right choice of technical means and materials. Detailed analysis plans lead to the fixing of renovation plans which are mostly not standardized. Therefore it is absolutely compulsory that special materials are available which are very often exactly and only designed foe one special project.

2.2 Building History

The history of a building is composed by a variety of interacting parameters. It may be the age of the building, how it was utilized, which building materials were used and which techniques were applied to erect it. Other circumstances, not mentioned here, may be of interest for certain projects. The detailed knowledge of the history of a building allows for the classification of the building into categories of historical value. It will detect changes in its utilization, clarify the situation on the availability and will give hints on the types of the original building materials. Furthermore, the knowledge of the history of a building could direct the analyst to investigations which would not be forced, because the importance would not become obvious otherwise. Some utilisation generates aggressive substances for buildings and certain trades were operating with specific substances that lead to damages over time. If, for example, the location of a former stable is known which was utilized later for some other totally different purpose, this is indicative to salt contamination of the masonry. Knowing that an ancient house was occupied by a tanner would lead the investigation instantly to the detection of masonry contaminated with chromium or other salts used earlier for the tanning of the animal skins.

2.3 Localisation of Damages

The renovation strategy can not start before fixing the extend of damage at a building. Data on type of damages like spalling, crack size and shape, efflorescence, moisture, area of defects, external impact and so on, have to be collected and must be documented completely together with photographs of the object. Only the evaluation of the significance of the detected defects can lead to the decision on which type of renovation system should be applied or whether it is principally possible, according to technical or financial constraints, to carry out the renovation plan.

2.4 Damage Analysis

The analysis of the damage goes along with a sampling plan of the object and the selection of the proper analysis methods. As the taking away of a sample specimen from a building means always an additional destruction of the original substance the right locations for the sampling at the building must be well organized in order to get a general overview on the type of damage by the lowest possible number of samples. In some cases it may be sufficient to analyze the damage by non destructive methods. This methods should be preferably used, if the results of such methods are generally sufficient to create a clear overview on the situation of the whole damage. Depending on the type of destruction at the building and the type of structure there is a great variety on the necessary data to be collected. The following enumeration of different material parameters that are necessary for a proper analysis are therefore only a selection.

Masonry Repair - The State of American Practice

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1. Overview

Given the large geographic and climatic range of the United States, there is not a single approach to the repair of broken and crack masonry. Despite this there are many strong trends and indications of heavy usage of certain techniques and products which are tending to dominate American practice. This paper reflects a summary of the findings of a 1997 phone survey of over 200 preservation professionals in the United States.

State of Art versus State of Practice: What is generally considered good practice in academic circles is often unknown or misunderstood in the commercial sphere. This problem of poor dissemination of technical information appears to be caused by several factors: a fairly young and extremely limited group of academic preservation programs, the heavy emphasis of these programs on non-technical subjects, the tremendous difficulty of finding and assessing laboratory work done as part of these programs, and the multi-disciplinary nature of the field, which makes locating articles on recent work difficult and does not help to develop a well established literature devoted specifically to the topic of preservation.

Historic Register Versus Non-designated Properties: The difference in treatment decisions and level of care given to buildings that have some type of historic designation and those that do not is significant. The approach does not appear to differ whether the historic designation is through the national registry or through state or local landmarking.

No Philosophical Consensus: Despite such documents as the Venice Charter and the Secretary of Interior's Standards in the U.S. there is little consensus in the American preservation community, even amongst its leaders as to the proper interpretation and the practical application of these guidelines. An example of this is the concept of reversibility.

Cost: Like most things, restoration choices seem to be heavily driven by preconstruction costs. Owners are generally unwilling to pay for sufficient preconstruction diagnosis, often culminating in a "sidewalk walk inspection" with binoculars. Frequently the outcome is improper diagnosis either of the root cause or of the scope of work needed.

Availability of Skilled Labor: The ease of obtaining skilled labor in certain regions or areas was definitely more difficult than in others. Given a general perception that good craftsmen are hard to find, those specifying treatment tended toward lower-tech solutions. Instead of considering recarving a piece of stone and replacing it outright, precast concrete was often favored since a mold could simply be taken for replication.

Contracting: The labor situation is further complicated by American contracting procedures. The general approach to contracting, particularly on public jobs is a sealed bid awarded only on the basis of the lowest price. Even with prequalification, the contracting is usually set up to prequalify the general contractor and not the masonry subcontractor.

Availability of Materials: The perceived availability to obtain replacement units most heavily influenced the treatment decisions and the recommendations for replacement materials, in terms of whether to replace in kind or to utilize a simulated or synthetic material.

Anchors: The repinning of wythes of brick and reattachment of both whole units and large pieces of terra cotta and stone are the most common uses of anchors. The nearly unanimous approach was stainless steel. Usage remains a bit of a mystery. Most designers unquestioningly accept manufacturers spacing recommendations with little thought as to how the anchors will be used. Two anchors seemed to be attracting a lot of attention in the U.S. market, although in many parts of the country their usage is still extremely limited. One anchor, originally marketed under the name of Helifix, is a drillable, spiral tie now available through several manufactures. The other is the Cintec- Harke anchor which incorporates material or mesh bags along the length of the anchor for grout placement.

Consolidation: Many remarked that little had changed in terms of available products and techniques in the area of consolidation for nearly thirty years. Most practitioners viewed consolidation as an expensive and uncertain alternative that they were willing to consider only as a final option for highly decorative or carved pieces that could not be replaced because of technical, fiscal, or historical considerations.

Grouting: Largely borrowed from Italian practice, void grouting is gaining popularity in the U.S. Unfortunately the approach is being adopted and specified with little critical assessment. Grouting is often being specified without a clear set objectives, no pre- or post-production testing, and with the grout mix being specified by the contractor. If this is the basis for future work, the success of this procedure in the U.S. is highly doubtful.

Patching: Due to the strong marketing success of Cathedral Stone (producer of Jahn), patching compounds have become extremely popular in the U.S. They are mostly used for stone, although their frequency for terra cotta repair is increasing, and two cases of brick patching were reported.

Mechanical Reinforcing: Unlike much of world practice, there is a strong disposition against any visible strapping, binding, or clamping of masonry. Despite the fact that this approach is often the most reversible, its aesthetic impact is considered unacceptable in U.S. practice and is only used as a temporary measure or when it will be completely out of sight.

Retooling, Rebuilding. and In Situ Repair: Although not common, there are many instances where designers have attempted to reuse the existing masonry. Retooling stone was suggested as a good option for deteriorated, rough cut sandstone, although it is not commonly done because of a perception of an unavailability of qualified stone cutters for the job. For brick, many reported attempting to remove the units, clean them and turn them around. For terra cotta and stone, a common approach was the use of a resin or lime-based grout to fill stable cracks for the purpose of either aesthetics or waterproofing. In some cases the terra cotta was actually removed, glued back together and reset.

Dutchmen: A popular approach to cracked units, particularly for stone.

2. Conclusion

Given the broad range of climatic conditions, availability of local building materials, and geographical influences it is not surprising that the U.S. should have a fairly broad architectural tradition. In this spirit, a highly varied approach toward restoration should therefore be almost expected. Unfortunately, American treatment decisions appear to be driven by many other factors including a poor technical grounding, insufficient investigative information, a contractor driven labor situation, poor dissemination of even basic tenets of good preservation and restoration practice to those in the field, a lack of financial resources, and a failure to come to a well understood philosophical basis for treatment selection.

Long-Term Stability of Joint Repairs in Building Construction

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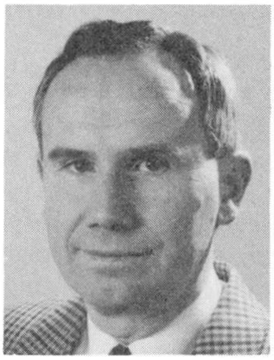

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Summary

Trial results with elastomer jointing strips based on polysulphide and silicone rubber are evaluated from the aspect of long-term stability. The authors have based themselves on the applications maintained since 1974. A report is given on the following results:

- Trial on structure
- Seal against driving rain
- Extension-compression strain
- Adhesion on concrete
- Tensile strength and elongation at break

The verified long-term-stability up to now is 23 years for the best joint solution investigated. So as to be able to determine the probable long-term stability, work is taking place on a test method.

1. Introduction

It is preferable to renovate the joint seals on external walls with elastomer jointing strips. At this point, a few results should be updated from the point of view of long-term durability.

2. On-site testing

Testing on a construction site is the most practical form of ageing test. Site trials provide proven values for long-term durability, but the maximum values actually achievable could be slightly or considerably higher than these and an accurate estimate is rather difficult to make. We present two selected applications of silicone and polysulphide jointing strips which have been dealt with by the writers since 1974 respectively 1979.

3. Test evidence

It was investigated six polysulphide rubbers PS I-VI, one silicone rubber SI and three primers P I-III.

- Watertightness to driving rain
  The test was carried out in a special rain chamber (see Fig. 1).

- Extension and compression strain
  The exercise was carried out on a special extension/compression test machine, the clamping part of which can be positioned in a temperature-controlled chamber (Fig. 2).
- Adhesion to concrete
  It can be concluded from the compression shear tests that the adhesion of jointing strips to concrete will not fail in the long term if it proved to be up to the mark in the first few years.
- Tensile strength and elongation at break
  When exposed to the open-air, the values of the tensile strength only drop slightly or even increase a little. The prediction period is an unknown quantity. As the elongation at break reduces continuously, it is suitable for predicting the long-term durability of jointing strips. We decided on a probable useful working life of 20 to 35 years for elastomer jointing strips.

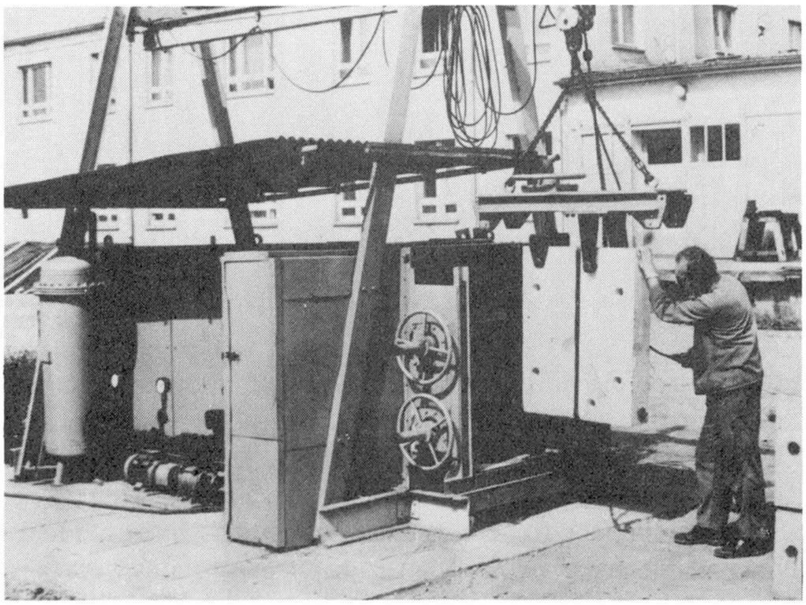

Fig. 1 Evaluation of the watertightness to driving rain in the rain chamber

4. Conclusion

The long-term durability of the elastomer jointing strips tested turned out to be very high. In order to be able to assess this property in the case of the addition of colouring agents and other formula changes, or even completely new formulae, new rapid tests are necessary. The authors are working on the general problem of the artificial ageing of elastomeric building sealants. However we shall not be reporting on this at this stage, but at the CIB World Building Congress which takes place in Gävle (Sweden) from 7 to 12 June 1998.

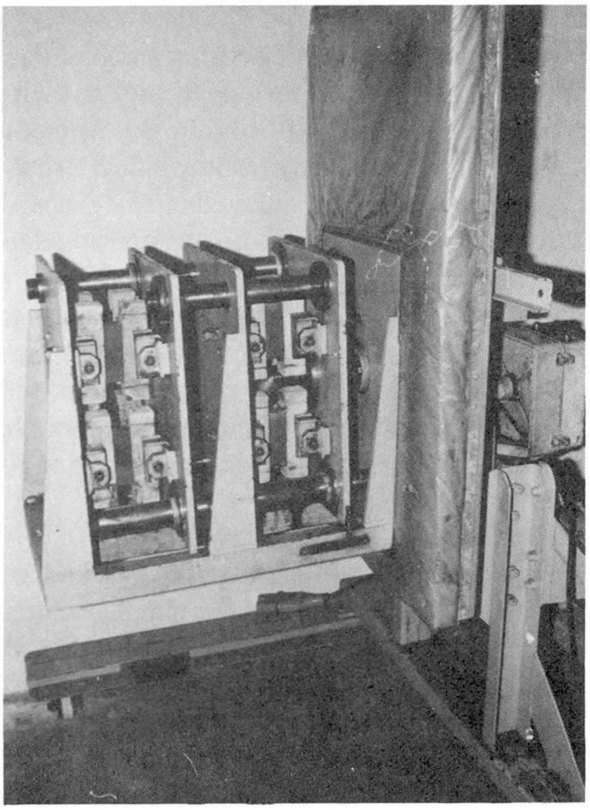

Fig. 2 Extension/compression test machine

Recyclable Housing: The Challenge lies in Design

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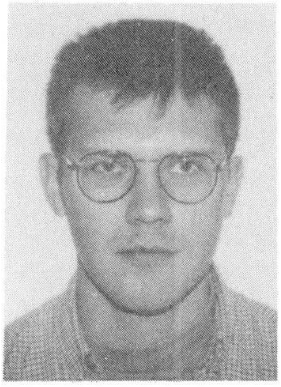

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Summary

Many misfits in our built environment come from the fact that building consumption is not acknowledged in architectural discipline. Recycling studies include the study of consumption and production and are therefore challenging as a 'locus' for future urban solutions.Legislation on design that includes recycling and re-use can change design procedures, the building process and materials production. To demonstrate some perspectives, a no-cost growing structure and novel fully recyclable and dismountable sandwich composites were constructed.

1. Introduction

The exponential increase of housing and building costs has a tremendous effect on social and city structures in Europe. People tend to stick to their heritage and thus increase traffic problems because of required work flexibility. Because of increased congestion and financial speculation, city cancers ruin previously healthy cities. Urban violence grows because of an urban poverty that is willing to live concentrated in city cancers. Many people are obliged to move into healthier regions. For those who can find some room to live in, building promoters and architects continue to impose non-existing social relations with building comfortable ruins around highways and airports. Displaced persons thus also voluntarily change more often from habitat and environment. Alternative co-habitation structures appear because of increasing costs. Building a house, i.e., the measure of a healthy economy, becomes rare. The building industry in cities becomes mainly employed in renovation. Most of the existing buildings are not adapted for integration of contemporary equipment, giving rise to further increases in building and labour costs.

This awareness also influences politicians and architects. Novel legislation appears on financial punishment of empty habitats. Current deconstructivist architecture is an expression of uncertainty. The only certainty we have is that what we build now, will block our future. The answer is to provide a possibility for change. In this paper it is examined how this can be done through development of recycling legislation. Because the construction industry in one of the largest producers of waste materials, the recycling and re-use of building materials is high on the political agenda. In practice, many building products and systems exist that have a potential for recyclability and dismountability. However, traditional irreversible building techniques continue to produce even more waste for the future. The recycling of these buildings can only lead to degraded products, because of contamination and ineffective design.

2. The End of Recycling

Stressing recyclability as a political prerogative did not lead to innovation in construction. The recycling business in the building industry tends to protect traditional building patterns. In Western Europe, recycling legislation has been directed towards concrete and masonry grinding. In Belgium, after the introduction of recycling legislation, exponential increases were observed in the number of concrete and masonry crushers, all of them at a relatively large distance outside of the city centre. Recycled granulates are used in road-building and concrete, creating a protective loop.

Other waste building materials are now seen as unwanted contaminants of the grinding process. However, in the near future, waste fractions from demolition waste will change, especially because of fast changing office and industrial constructions. For example, in Europe today, more than five million tonnes of plastic materials are used in construction each year and experts predict that this figure will rise to almost eight million tonnes by the year 2010 (APME 1995). Today only about 10% of the plastic consumption in the (re)construction industry is found back in construction and demolition waste (United Nations 1992, Casamassima et al. 1993).

Non-conventional building materials are usually carefully hidden in walls, roofs and floors. Think for example about cables, roofing, insulation, adhesives, furniture, polymer concretes and cements, and so on. In future recycling, today's recycling incentives will make less sense due to the fact that such materials are irreversibly connected to the main waste stream. For example, contamination of concrete and masonry rubble with more than 10% of gypsum, cellular concrete, lime stone, fibre containing concrete and/or other materials will lead to a refusal of the waste by the concrete and masonry crusher. Metals that are for more than 30% contaminated with concrete or organic products will be refused at the metal recycler. Insulated glass and mirror glass are refused by the glass recycler. Paper contaminated with plastic, glass or fibres will not be accepted at the paper recycler (Van Breusegem et al. 1995). Preserved and painted wood will mostly be denied as chemical waste (BW 1994). Polymers are put to disposal or burnt. Another consequence is that some these novel building products, being re-usable, will be damaged or irreversibly contaminated when they have to be dismounted and recycled. Pretending that future technology will manage the highly contaminated building waste streams is asking for a waste of energy. Many cleaning technologies have proved to be contaminating for the environment. Contamination should and can be avoided at the production stage, this is by the designer, the architect or the city planner. Building lords and contractors should promote the production of dismountable consumer buildings.

3. Towards Dismountability

Unlike recyclability obligations, dismountability and re-use obligations can lead to important changes in the way we design and build. Dismountability obligations might bring some solutions for current building problems, but also innovation in the building (product) industry.

Once the building is constructed, maintenance is now often forgotten. Maintenance is however an important economic issue. For habitats in Belgium yearly maintenance costs are about 1,27 - 1,60% of the initial building costs (Delrue 1982). This means that in 60 to 80 years a capital equal to the initial cost has to be spent on maintenance. These costs are higher for public buildings.

Saving Buildings by Relocation

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Summary

The solution of saving special buildings from demolition have been applied on a relatively large scale in Romania by their remplacement.
The paper synthetizes the national experience in conceiving and technology of realizing the displacement of the buildings, consisting, mainly in:
-the decision of remplacing a construction and the preparation works;
-the establishing of motions in space which are to be made;
-the estimation of financial and technical resource consumption.
In conclusion the advantages of the saving solution of the buildings by remplacement using translation, are presented.

Keywords: building, saving, systematization, remplacement, translation, technology, equipment

1. The Decision of Remplacing a Construction

Whitin the systematization of the urban zones, throughout the years, there have been met serious difficulties in preserving some constructions,valuable by their architectural style and historical significance or even by their good condition in which they were preserved.
The solution of saving these special constructions from the demolation, by remplacement using the translation, represents a qualitative leap in the construction activity. By this procedure, in comparison with a new construction , the buildings are preserved in the conditions of a substantial economy of materials and human resources, in a reduced execution time and without evacuation during the translation period.

2. Technology of Translation

The translation technology imposes the preservation of the equilibrium conditions and respectively, of the construction displacement within admitted limits. These requirements are solvable by making a plane girder network loaded perpendicularly on their plan, called "bearing

frame". It is a new construction element , made from reinforced concrete, realized in the zone where the construction is cut from the fondation. The weight of the construction is taken over by the bearing frame which distributes it to the supports imposed by the technology, e.g. rigid supports on the presses respectively, elastic supports on bogies.
From the experience of the over 25 works of translation performed after 1982 in Romania there can be established five types of motions which a construction can execute in space:
-the lift as well as descent of the construction, which are made with hydraulic presses;
-the displacement of the construction on a horizontal plane and respectively in slope, which are realized according to the technology designed with electric cable hoists (for pulling) and / or with hydraulic appliances (for pushing);
-the rotation of the construction; it is performed by the application of a horizontal force at the end of a beam of the supporting system.
The saving by translation of a large number of constructions also led to the establishment and check of the tools,equipments, of measuring and control devices as well as of the admitted tolerances for an entirely safe execution of this technology.

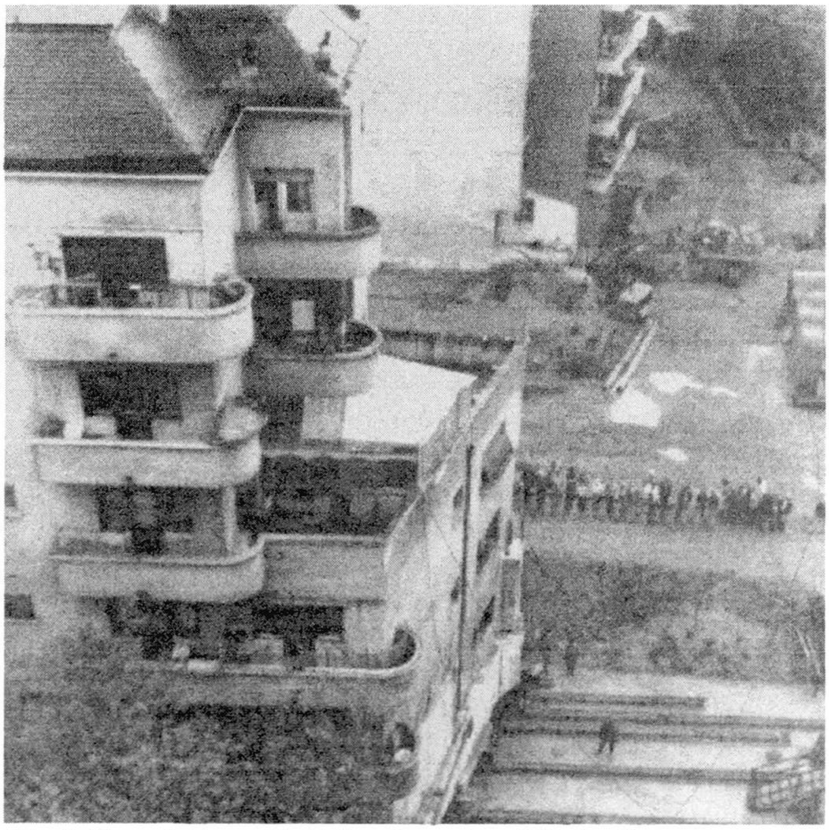

Fig.1 Translation of building from Aurel Vlaicu Street, Bucharest

The remplaced constructions were churches, dwelling and social-administrative buildings, hospitals, memorial houses etc. Fig. 1 presents the displacement of a seven story block of flats in Aurel Vlaicu Street, Bucharest , on a built surface of 2245 m^2 and a structural weight of 5100 tones. The considerably height building was 14.4 m displaced at a speed of 1.9 m/h by means of 52 bogies pulled by two electrical cable hoists.

For the constructions saved in Romania using the translation there has been established a cost indicator between 29 and 47 % from the value of a new equivalent building. The basic materials used were the cement and structural steel and they represented about 25...30 % from the quantities of these materials used at a new construction.
The execution of some translation works is also accessible in the future to other construction companies not only in our country but also abroad, in the conditions of using a specialized team and well equiped for this kind of works. The translation procedure for saving the buildings may avoid the evacuation of inhabitants or the intrerruption of their activities during the translation works and it also preserves entirely the construction in economical conditions.

Recycling of Building Wastes - A Real Perspective for Bulgaria

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1. Introduction

The recycling of the building wastes, which is a modern approach for preventing the environment from pollution and, in general, for restricting the demolition of our nature is one solution to that problem. At the same time, because of the mostly solid and non-toxic nature of the building wastes, the recycling is very successful without by itself additionally polluting the environment. During the last fifteen years, the recycling of building wastes developed intensely in a number of European countries, Japan and the USA. However, for Bulgaria, the issue is still a new one, despite the significant changes in the environmental legislature, directed towards preventing the environment from pollution.

2. Some achievements in the recycling of building wastes

Largely, the building wastes are recycled in the form of aggregates because of the broad range of possibilities for their implementation: as general bulk filling, as filling in drainage activities, as sub-base material and as aggregates for new concrete. Depending on the origin and the constitution of the building wastes, a number of approaches for their recycling could be used. In comparison to the production of broken aggregates, the basic differences are in the methods employed for removal of the undesired components. The major peculiarities in the physical properties of the recycled aggregates are caused by three factors: their heterogeneity, the presence of impurities and the attached mortar and cement paste. The high water absorption is the most important difference between the physical properties of the recycled aggregates and those of the natural aggregates. Compared to the concrete made of natural aggregates, the concrete made with recycled aggregates employs a number of drawbacks. These drawbacks are the more crucial the larger the quantity of fine recycled aggregates included in the concrete is. The use of only coarse recycled aggregates makes possible the production of concrete which properties go very close to those of the typical concrete of resistance classes B25-B35. In 1993, RILEM recommended a project for common European Code concerning the utilisation of coarse recycled aggregates.

3. Perspectives for Bulgaria

In general, Bulgaria has a significant amount of natural deposits of the inert materials, necessary for the building. There are, however, several regions, especially in the North-eastern part of the country, that experience shortage of some concrete aggregates. Most of the producers of inert

materials can not obtain the investment capital necessary either for maintenance and technological renewal, or for the transportation of their production. On the other hand, an establishment of recycling process for the building wastes will resolve some of the problems concerning the shortages in the supply of natural inert materials.
Especially important for Bulgaria is the solution of the problem created by the non-utilised building panels that will never enter a construction cycle. We should not ignore also the fact that a significant part of the panel-constructed apartment-buildings in our big cities are about to end their predetermined exploitation periods. The demolition or at least modernisation of a great number of building constructions, that will soon have to be initiated, is expected to create a great number of concrete and reinforced-concrete wastes.
Bulgarian legislation concerning the definition and utilisation of the concrete aggregates addresses predominantly the natural aggregates. In fact, at the moment, all the standardising documentation in the field of the building activity, is a subject of re-estimation and actualisation, in accordance with the trend common for all the laws of Bulgaria to be amended and reshaped in accordance to the European Law. One proof is the vast majority of both amended environmental laws and newly accepted ones. It is to some extent regretful to note that, so far, most of the above changes are more or less of a positive character rather than realised in practice, but they give "green light" to the development of activities for recycling the building wastes.

The activity of recycling the building wastes is for now concentrated largely on the development of the theoretical basis for the future process, and on the search for possibilities for its financing.
A scientific collaboration has been initiated between the Central Laboratory of Physico-Chemical Mechanics with the Bulgarian Academy of Sciences and the Laboratory of Materials and Structures with the Artois University in France before three years. A joint research project concerning the problems of the durability of the concrete produced by recycled aggregates is presented for financing with the Nato's program "Science for peace".
A pioneer project called "Recycling of demolition building waste materials", directed to their re-use as concrete aggregates has been prepared with the participation of representatives of the Municipality of Sofia, the municipality-owned company "DOMOSTROENE" and the Bulgarian Academy of Sciences, with the collaboration of the group KRUPP HAZEMAG. The project participated into a contest, organised by the National Trust Ecofund (NTEF). The NTEF is intended to finance projects concerning short term solutions of ecological problems in accordance with the agreement concluded between Bulgaria and Switzerland.

4. Conclusions

As final notes, the following perspectives for the practical implementation of the recycling of building wastes in Bulgaria could be outlined:
1) In the beginning, economically feasible will be the construction of one mobile installation for the recycling of concrete and reinforced concrete wastes;
2) Some steps could be undertaken to organise the realisation of the recycled aggregates in the road-construction as well as in the construction of small-scale elements.
3) Having in mind that one major obstacle to the recycling of building wastes is the initial financing, some foreign investments could be attracted.
4) The collaboration at different levels among institutions, enterprises and leading experts in the field of recycling and reuse of building wastes will be a necessary and productive step on the way to organising the recycling of building wastes in Bulgaria.

Replacement of Masonry - Important Selection Considerations

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1. Overview

Prior to locating a replacement source, important decisions must be made as to the extent of units needing replacement versus those that can be left in place for in situ repair. This will in large part be dependent upon the diagnosis of the failed unit. Expensive restoration or preservation activities will be useless, if the cause of deterioration or destruction is not identified and eliminated, or at least mitigated. Whether unit replacement is done may be also heavily influenced by the amount of financial resources available to the project and whether or not new replacement material can be found or produced in a timely manner. Too often this last consideration goes unexplored until the contract is let, the building is scaffolded, and the project is underway. It is not unusual that the location, manufacturing, and delivery of acceptable materials may take several months, if not the better part of a year. If an appropriate supplier is not located prior to the award of contract, delays of an unacceptable length may be expected.

The other major decision that needs to be made prior to approval of replacement units is whether the building's color will be matched clean or dirty. It is more common than not that masonry repair of a structure will be done without any cleaning of the units. If the units are to match the cleaned condition but the building is not being cleaned, the new units will stand out for several years unless some type of artificial staining or dirtying process is applied. An extreme example of this was done using kerosene lamps in order that the units had a smudged appearance at completion of the construction. If the units are matched to a dirty building, they will never look right should the building ever be cleaned. Additionally, there is no assurance that the units will weather in the same manner as the dirtied ones. It is for this reason that it is always recommended to match the cleaned condition, although this is often not done.

A situation unbeknownst to many who specify unit replacement is the amount of damage to adjacent units that may occur during extraction. This is especially true if only isolated units are removed. The nicking and chipping of nearby units is a common problem. Bricks pose the extra difficulty of the presence of header units being embedded in the second wythe. The situation with terra cotta is even more challenging given the elaborate set of pins, toggles, bars, and hangers that were often incorporated. With all masonry, but most often reported with terra cotta, the building has gone through irreversible movements either due to moisture expansion of the units, frame shrinkage, settlement, or a host of other factors. The result is an unknown and often delicate redistribution of stresses within the masonry, which may cause the sudden and unexpected cracking of nearby units when the stress in one portion of the wall is released during the removal of a unit or units. In such a situation, stress relief joints may need to be cut into the building along the mortar joints, at least temporarily.

Most bricks were originally made on site using locally available clay and sand often from the project's property. This highly localized approach resulted in a wide variety of sizes, colors, and finishes across the country that were extremely specific to a particular locale because of the local clay. By the late nineteenth century automation was revolutionizing brick making, mostly through the introduction of pug mills. This allowed larger scale operations, a better mixed and more consistent clay product, and greater uniformity in size and tolerances. The other important move towards automation came in the form of the tunnel kiln. Unlike in a stationary kiln, tunnel kiln bricks were exposed to basically the same heating and firing throughout the process. The result was much more uniformly fired individual bricks and more consistently fired batches. Visually, the end products had much more of a single color both across the batch and within a single unit.

Another major change in American brick making is the current move towards a smaller and modular sized brick. Because of this trend, non-modular brick is becoming increasingly difficult to find. If new brick is to be used for historic replacement, this leaves only a few options because of the size difference. Even with a custom run, many of the problems of matching remain unaddressed. One of the most common is color. Because of the change in production techniques, an entire brick firing will be largely the same color. Historic bricks possess a tremendous amount of color variation, even within a single unit, depending upon its orientation to the heat source during firing. Additionally, the clean edges of a new brick made in accordance to ASTM will have extremely sharp, crisp edges that will undoubtedly be easy to differentiate from bricks that have stood the test of time for many decades, if not centuries.

The final area to consider for matching is physical performance. Because historic bricks are relatively soft and porous by today's standards, it needs to be decided weather it is or is not advantageous to try to match these characteristics as well. For instance, a typical turn-of-the-century brick might have a crushing strength of 3,500 psi, whereas its modern equivalent could easily be three times this.

In some ways similar to the trends in the brick industry, terra cotta production has become more consistent and more uniform through advancements and sophistications in automation. This has generally produced a more durable and reliable product. Unfortunately, like brick, it has created a situation in which it is harder to match the wide variation of tones that appear on existing structures. Improved manufacturing processes have greatly minimized the range of colors produced during firing. The narrower range of tones has resulted in building appearing to be patchy where a large number of units are replaced from one section. Another problem in glaze matching. Many of the rich dark colors of blue, red, and green, and even some of the metallics are nearly impossible to match. The chemicals in current use are different from those in the early part of the century and few of the original formulas are even known. Given the additional factor of weathering, it is unclear whether this supplemental information would be useful. The exercise of color matching is even more complicated than this. Similar to the problem of matching weathered unit, much of today's terra cotta shows extensive crazing. Extensive crazing may substantially change the color of a piece. If the color of the new unit was selected to match exactly the color of an uncrazed portion of glaze, the contrast between new and old units may be startling. How these new pieces will then weather also becomes a major issue.

Stone, as a material that is used with little alteration or processing, differs in some significant ways from brick or terra cotta. Unlike these processed masonry units, the desired look and quality of the stone must be very close to what is taken from the ground. To date, stone cannot be dramatically enhanced or altered in a chemical or physical manner that would allow it to better match an existing unit or showed improved performance characteristics. The challenges this embodies are highly dependent upon the stone that is being replaced.

2. Conclusion

Finding suitable replacement material for masonry units is not an easy task. Locating appropriate sources for raw material and manufacturers with the proper equipment and a skilled labor force may take many months, in addition to the extensive amount of time that may be needed for quarrying or production. To successfully select replacement units important decisions must be taken prior to contracting regarding expectations for exact color matching, building cleaning, and variability tolerances within the units.

Strengthening of Structures with Carbon Fibre Strips

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Summary

Structural strengthening has always been state-of-the-art technology. Various reasons and causes such as change of use, damages or calculation errors are only some examples for cases where strengthening will become necessary. Conventional measures like strengthening with reinforced shotcrete are costly and often result in disturbingly enlarged cross-sections. Measures using bonded steel plates permit smaller cross-sections: A height increase will only become necessary if the safety margins in the compression section of the concrete are exhausted. Similar to the above described strengthening method with steel plates, but more elegant and thereby more versatile is the use of carbon fibre strips, a material which has proved ist test of practice long ago, especially in aircraft construction and in the formula-one, as well as in the manufacturing of sports articles (tennis-rackets, etc.)

Structural Strengthening with Carbon Fibre Strips

The classical theory of steel reinforced concrete is based on the model of a truss girder with horizontal ties and struts and diagonal members. The function of the horizontal as well as of the diagonal struts (as far as the values „remain within certain limits") is taken over by the concrete, the function of the horizontal tie is taken over by the reinforcement . In case of change of use, damages or calculation errors it may become necessary to strengthen the horizontal tie, for adding tensile strength to the above truss girder model. This works only under condition that the cross-section in the compression section retains the appropriate reserves.

Bonded, additional external reinforcements, based on carbon fibre strips, are worldwide proved for approx. 10 years and have reached break-through in reinforced concrete construction. A general Technical Approval with the Number Z-36.12-29 of the „Deutsches Institut für Bautechnik (DIBt)", Berlin, is available for the carbon fibre strips and for the adhesive. No matter which type of girders on cantilevered sections are concerned, the carbon fibre strip can in principle always be used wherever tensile forces have to be dealt with in the sense of truss girder analogy. The higher material cost of carbon fibre strips compared to steel plates is compensated by much easier application and by special advantages line unlimited lengths, easy handling and corrosion resistance. The strengthening on the rear side of a wrongly dimensioned supporting wall is therefore an example for unrestricted use of carbon fibre strips , whereas bonded steel plates are unsuitable because they cannot safeguard longterm corrosion protection.

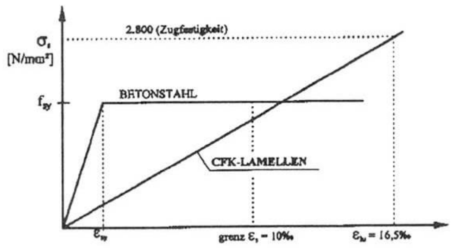

Fig. 1: Tension/elongation line steel/carbon fibre

Contrary to steel, (see characteristic tension-elongation diagramme in Fig. 1), the carbon fibre strip shows an ideal elastic behaviour until break . The tension σ is ideally proportional to elongation ε until break. The break occurs after approx. 16‰, the permissable elongation when strengthening a beam is limited to 8‰ in the Approval.

As long as the ongoing research is not yet completed, transmission of compressive forces must be distributed with steel plates for the time being, analogous to the principles of steel reinforced concrete with the incorporation of ring bars. Carbon fibre strips are suitable for reinforced concrete, pre-stressed concrete, timber and steel. Strips are available with various E-moduli (3 types with 170, 210 and 300 Gpa). The thixotropic, filled epoxi adhesive is universally suitable for concrete, steel and wood. Two practical examples of strengthening measures on bridge constructions show the possibilities for the use of carbon fibre strips:

- Bridge Niederwartha (Dresden)

Unlimited use is now re-established after extensive repair measures in combination with carbon fibre strip strenghtening.

- **Bridge Meiningen**

On this project re-strucuring relied on combined measures: For the transmission of compressive forces, reinforced concrete wa cast on top whereas the tensile strength on the underside was increased to the required level by carbonfibre strips as can be seen in fig. 3.

- **Bridge Luzern**

Wooden bridges are often classified as monuments. It is therefore essential that the increased safety demands are met with almost unvisible measures without changing exferion appearance.

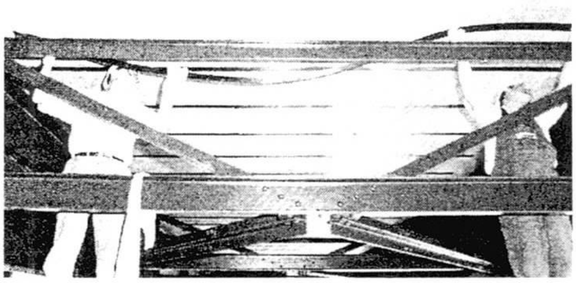

Fig. 2: Bridge Meiningen

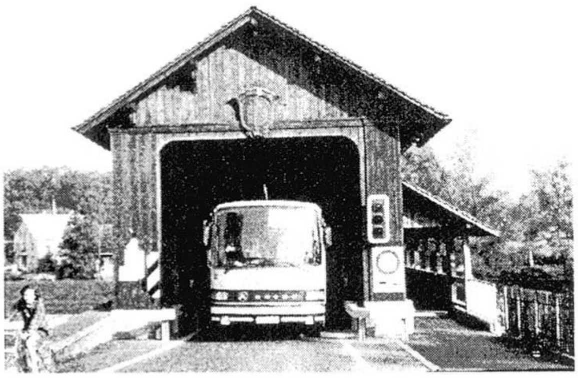

Fig. 3: Bridge Luzern

Flexural Reinforcement of Concrete Beams using FRP Plates

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Summary

With reference to the restore and strengthening of reinforced concrete structures, the *Wrapping* technique using FRP materials, appears rather effective, for results which can be obtained and the easiness of applications in situ.
Experimental tests carried out on beams reinforced with FRP plates, have shown particular failure mechanisms which are different from usual ones characterising reinforced concrete structures. For this reason, the dimensioning and disposition of FRP plates need of a particular attention.
The purpose of this paper is to define a theoretical model for the prediction of the real flexural behaviour up to failure of concrete beams reinforced using FRP plates.

Keywords: Reinforcement, Concrete, Flexural Behaviour, FRP Plates.

1. Analysis of a reinforced concrete beam strengthened with resin-bonded FRP plate

Since 1960, the strengthening of reinforced concrete beams using steel plates and epoxy resin has represented an efficient methodology for structural reinforcement. In fact, this procedure presents many advantages, i.e. low cost, easy installation and very small variation of the element dimensions.
On the other hand, the production of composite plates (Fibre Reinforced Polymer) having very high tensile strength, high fatigue and corrosion resistance, small weight has encouraged the substitution of steel plates with the FRP ones.
The strengthening of reinforced concrete beams with FRP plates have been described by many researchers that have initially tried to quantify the increasing of the capacity and stiffness obtained with external bonded FRP sheet, putting in evidence the dependence of this system from FRP strength and elastic modulus and resin properties.
Moreover, a large number of experimental tests have shown that the failure of beams strengthened by epoxy bonded FRP plates is strongly related to the properties of concrete-resin-plate interface; in fact, besides the failure for crushing of concrete or tensile rupture of plate, the tested beams collapsed because of debonding of plate at the interface (peeling) and failure of concrete layer between the plate and longitudinal steel rebars (concrete cover). By the light of these experimental results, an interesting problem of research with reference to the concrete beams externally reinforced with FRP plates, has been and is still the theoretical prediction of the flexural behaviour and modes of failures of the strengthened element, in order to correctly define its capacity and stiffness.
In this paper, with reference to a beam element having infinitesimal length, a function which correlates the interface shear stress to the stress characteristics (shear and bending moment)acting in a cross-section is obtained.
This function is also used in order to determine the moment-curvature diagram, taking into account the slip at the concrete-glue-plate interface.
The proposed model is developed adopting the following assumptions:

- concrete constitutive law is defined by C.E.B. parabola-rectangle;
- the steel constituve law is defined by a bilinear curve taking into account the effect of strain-hardening;
- the plate constituve law is linearly elastic up to failure;
- the interface glue has an elastic-perfectly plastic constitutive law;
- the concrete cross-section remains plane after deformation.

2. A numerical application of the model

Considering a simple supported plated beam subjected to two concentrated loads, symmetrical about mid span, the proposed model allows to obtain the moment-curvature diagram of the cross-section (fig. 2.a) and the diagram of the interface shear stress versus the shear force (fig. 2.b).

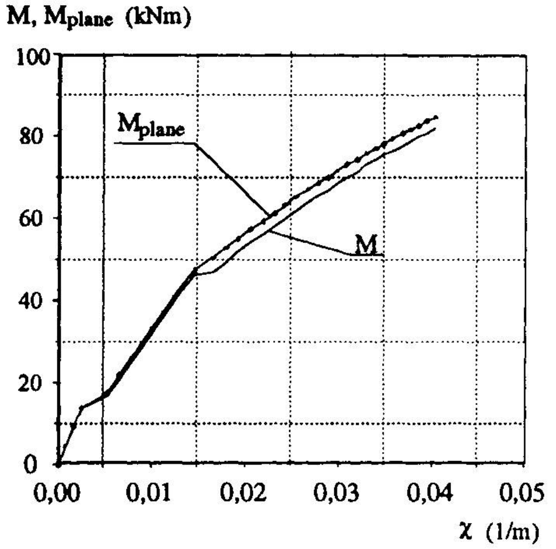

Fig. 2.a: $M-\chi$ Diagram

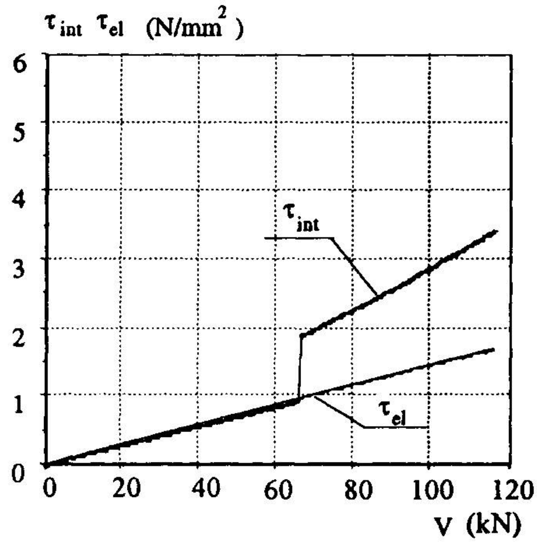

Fig. 2.b: $\tau - V$ Diagram

It can be observed that the assumption of plane behaviour for the strained cross-section does not allow important differences with reference to the prediction of the ultimate bending moment ($M^u_{plane} = 1.034M^u$); the same consideration is not valid for the evaluation of the interface shear stress, necessary in order to predict failures for peeling or debonding of concrete layer between the plate and longitudinal rebars.

In fig 2.3.1.b the diagram of the interface shear stress calculated by using equation (2.2.5) and the diagram of the one calculated considering a linearly elastic behaviour of the materials are indicated. As it can be noted, the two diagrams are almost coincident up to the shear force reaches the value correspondent to the yield of steel rebars. At this value, the shear stress τ_{int} non linearly calculated has a discontinuity and becomes much higher than the one calculated in elastic hypothesis.

In the case of beams strengthened with steel plates (the steel used for the plates is generally the same one used for the longitudinal rebars), the reinforcing plate, normally, reaches the yield before the steel rebars, being its strain greater, and the interface shear stress correspondent to the ultimate shear force of the beam can be calculated in elastic hypothesis with a good approximation.

This is not valid for the FRP plated beams (in fact the FRP plates have a linearly elastic behaviour up to failure). In this case the yield of the steel rebars occurs, in many cases, before the collapse of the beam; for this reason, the interface shear stress has a significant discontinuity which cannot considered adopting an elastic formulation.

The possibility to evaluate the interface shear stress varying the applied load, allows a numerical comparison with the admissible value of the interface shear stress τ_{adm} correspondent to the failure for end peeling or longitudinal debonding of cover concrete.

Actually, some empirical and/or theoretical formulations which permit to calibrate the value of the admissible shear stress τ_{adm} are proposed.

On the other hand, the different numerical values proposed (the admissible shear stress depends strongly from a large number of geometrical and mechanical parameters) and the significant shear stress concentration at the end of the beam make necessary a research on these problems, in order to adequately predict the numerical value of the ultimate load when the collapse of the FRP plated beam appears in the above-mentioned premature modes.

Strengthening of Bending Concrete Elements with Epoxy-Bonded Plates

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Summary

The paper presents the results of four-point bending tests performed on short reinforced concrete beams strengthened in flexure by externally bonded steel as well as carbon fibre-reinforced plastic plates. For the gluing of the plates to the concrete surface the commercial epoxy adhesive was used. The localisation of the shear-peeling crack at the plate end, which initiated separation of the strengthening plate from the beam surface, occurred at both used types of external reinforcement at approximately the same flexural load. On the other hand, externally bonded plates held the concrete together and delayed and hindered crack development. Due to strengthening also considerable changes of strain distribution along the beam height at the middle of the beam were detected.

Keywords: bending strengthening, steel plates, CFRP plates, epoxy adhesive

1. Experimental programme

The aim of our experimental work was to study critical situation when peeling or/and shear failure prevailed over the flexural failure of the concrete reinforced (CR) beams strengthened in flexure with externally bonded plates. Also the influence of the external reinforcement to the global and local deformation ability of beams was studied. For these reasons four-point bending test was performed on short concrete beams (150x150 mm in cross-section and 1000 mm long) internally reinforced by two ribbed bars $\phi 12$ and stirrups. As external reinforcement, mild steel plates as well as CFRP plates (SikaCarboDur) were applied and for gluing the plates to the concrete surface the epoxy adhesive Sikadur-30 was used. For each type of the external reinforcement two beams were tested together with one reference specimen without externally bonded plate. The loading speed in the elastic range was equal to 5kN/min. During each test flexural forces and deformation characteristics of the test specimen were simultaneously measured and crack pattern was traced and registered. Deflection of the beam was measured by LVDT transducer and concrete strains along the beam height were measured by electronic deformeters. Strain gauges were used for the measurements of the concrete as well as plate strains at the lower surface of the beam.

2. Main test results and discussion

The steel plate considerably increased the stiffness of the beam up to the localisation of the shear-peeling cracks at the plate ends. In case of the CFRP plate the increase in the beam stiffness was not significant. On the other hand, both types of the externally bonded plates held the concrete together and delayed and hindered crack development. This is probably the cause for significant change of strain distribution along the central cross-section of the beams, detected during the tests. After the initiation of the strengthening plate separation, the shape of the strain diagrams changed from straight to bi-linear line. Precisely, along the lower 50 mm of the height of the cross-section concrete strains seem to be approximately constant (steel plate) or even declined towards the lower strains (CFRP plate - Figure 1).

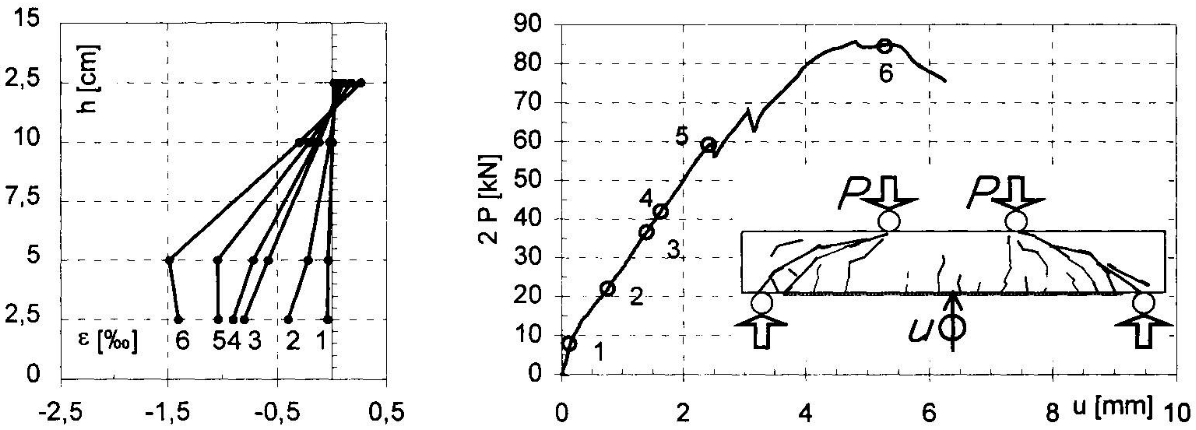

Figure 1: Concrete strains along the beam height at different flexural load levels and final crack pattern for the beam with externally bonded CFRP plate.

The typical failure mechanism of the test specimens with the externally bonded plates was as follows. Soon after the flexural cracks occurred in the middle span between the points of load application, flexural cracks at both ends of the plate were initiated. With increased loading this cracks transformed into diagonal tensile cracks, which were arrested by the internal stirrups. At the same time separation of the strengthening plate occurred due to the localisation of a shear-peeling crack in concrete just above the glue layer. This happened at both types of external reinforcement at approximately the same flexural load. As the process of the plate separation continued, one of the diagonal tensile cracks started to open and crack faces started to slide mutually. Due to relatively small spacing between the stirrups, beside the localised diagonal tension crack also more distributed shear cracks occurred in the shear span (Figure 1).

3. Analytical approach

The shear and peeling stresses at the end of the strengthening plate were estimated in a moment when the plate separation started. For this purpose the closed analytical formulae were used. The calculated peak shear stresses are considerably lower than the bond shear strength between the epoxy layer and the concrete. On the other hand, peeling stresses are close to the bond tensile strength between the glue layer and the concrete. Therefore, it can be concluded that high peeling stresses at the end of the strengthening plate were responsible for the separation of the steel as well as CFRP plate from the beam surface. As and example the calculated peeling stress are presented in Figure 2.

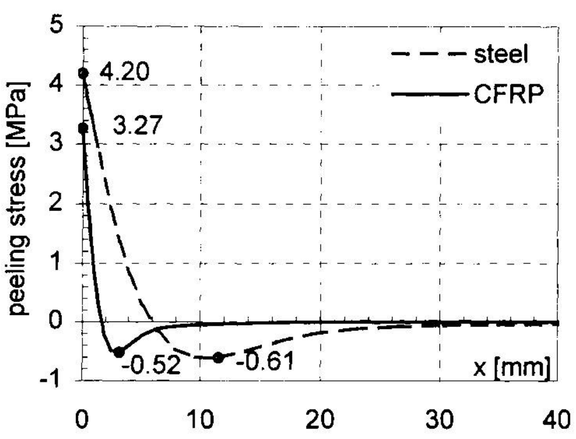

Figure 6: Peeling stresses at the end of the strengthening plate in the bond zone

Due to good agreement between the experimentally and the analytically obtained results it seems that the shear and peeling stresses in the bond zone could be controlled by theoretical calculations. This approach was already used for the design of long bending reinforced concrete elements with externally bonded steel and CFRP plates, in order to prevent shear-peeling failure before the bending load-bearing capacity of the elements would be exhausted.

Strengthening Beams in the Shear Zone

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Summary

The paper consists of two parts. The first one presents the problem of strengthening the beams damaged in the shear zone in real industrial building. The analysis of serviceability and limit states was made and two ways of strengthening were design. Second part presents the experimental study on two reinforced concrete beams, underreinforced in the shear zone. One of them was strengthened by externally epoxy bonded steel plates, after loading of about 70% of its ultimate capacity.

1. Strengthening the concrete girders in the Textile Factory in Lodz

Two of all two-span box-girdes of the saw-tooth roof konstruction of the spinning mill building were significantly cracked, closed to the intermediate support. The roof consists of triangular concrete prefabricated frames supported on these girders and covered with bearing bush plates. The main beams have the cross-section dimensions of 1.00×1.35m and the spans of 18.0m. Their inner spaces are used to pull out air from the air-conditioning. Structural, statical and limit state analysis has been done, based on the investigation carried out in the building. There are few diagonal cracks on the side surfaces of the girders with the widths of 0.3 to 1.0mm, exceeding the limit values. The study of this case shows, that diagonal cross-section with the maximum crack width works in the worse conditions of the combined shear and bending. There are also effects of stresses due to shrinkage caused by the pull out air inside the girders and dry of the concrete. Ultimate shear capacity of the craced sections was calculated by the Polish Code method. The design shear resistance exceeds the shear force due to load, but with respect to serviceability limit state, two alternatives of strengthening the craced region were design as shown in fig. 1. Alternative b) represents the plate bonding technique and alternative a) is the traditional method of mechanical bonded externall stirrups.

2. Experimental tests

There were tests made in the laboratory of the Concrete Structures, Technical Univ. of Lodz, to check out shear behaviour of RC beam strengthened by epoxy resins bonded steel plates under repeated load (see fig. 2).

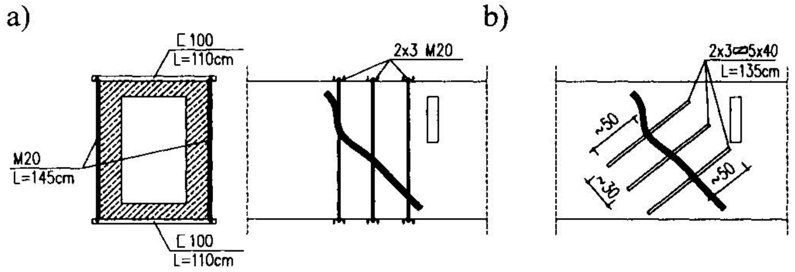

Fig. 1. Designed alternatives of strengthening

Two beams (b=0.20m, h=0.30m) were made as underreinforced in the shear zone. The control beam BS-0 was not repeired and the beam BS-2 was first preloaded to about 65% of its ultimate load and precraced. Next it was strengthened by steel plates 5×40mm, bonded and anchoraged to side faces in the support region using epoxy resins. Both beams failed as the result of diagonal tension cracking in the shear span regions. The effectiveness of the strengthening was 19 percent. The strengthened beam BS-2 failed prematuraly by tearing off the concrete and plates before yielding of the external reinforcement. The stresses in the steel plates at failure were only $0.19f_y$. Their full ultimate capacity was not developed. But the stirrups were significantly unloaded (about 70%) by the external reinforcement comparing with the control beam, short before failure - see fig 3. It apeared to be important problem how to design the strengthening to avoid the premature failure of the beam. The strength of repaired concrete should be high enough and the maximum shear and peeling stresses at the interface should not exceed the limiting values at which tearing of the concrete takes place.

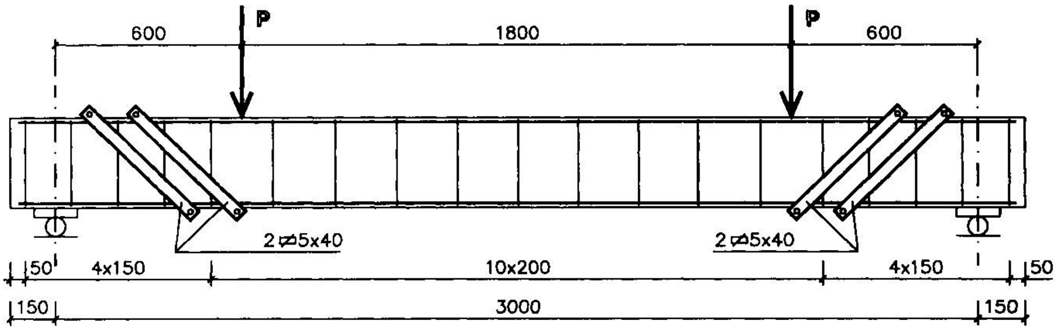

Fig. 2. Beam BS-2

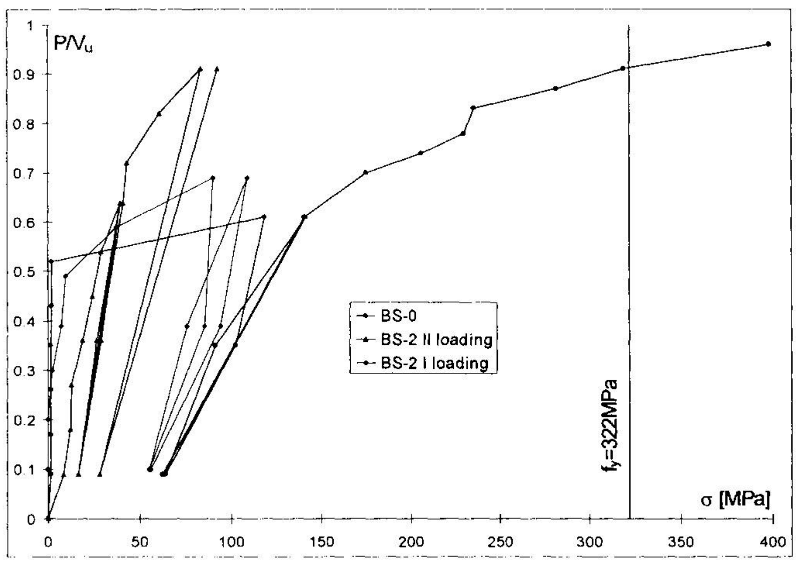

Fig. 3. Stresses in stirrups

Reconstruction of Buildings with Concrete Filled Steel Tubes

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Summary

This article presents examples of supporting constructions from steel pipes, filled by concrete for the reconstruction of buildings. Concrete filled steel tube is applied as struts, which support building on stories of dwelling houses; for reinforcement of foundations of stuffed piles; for reconstruction of production building as supporting structure. The efficient use of concrete filled steel tubes in the reconstruction of buildings is demonstrated.

1. Introduction

The concrete filled steel tube is the structure of steel pipes, which is filled by concrete. Special properties of steel and concrete are used effectively in these structures. A pipe-case carries out functions as longitudinal, as lateral reinforcing. The lateral pressure of the pipe prevents an intensive development of micro cracks of a break in a concrete core, which bears stress more excellent the compression strength in the conditions of all-round compression. So the steel pipe, filled by concrete, is protected from the loss of stability as local, as total.

The considerable volume of the experimental-theoretical researches of the concrete filled steel tube was conducted last years in the Poltava Technical University [1,2,3]. It allow to receive sufficiently basing methods of the calculation and designing of the concrete filled steel tubular members. In present time the building from the concrete filled steel tube is not recognised in our country, though erecting of these structures is in progress.

2. Report

There are many interesting examples of use the compressed concrete filled steel tubular structures in view of columns as in industry, as in civil engineering. The experience of use of the concrete filled steel tube in special constructions, designed and built by us in different years, presents the indubitable interest. For example: the concrete filled steel tube bearings were built for the transport gallery on the reserve storehouse of ore at the guarres of the mining-concentrated plants in Krivbass (Fig. 1). These bearings bear the large vertical load (more then 10000 kN), besides that, the horizontal efforts action on them (wind and pressure of ore at unloading from one side bearing).

Bearings are four-branch multi-storey frame structures. The branches and crossbars are made of concrete filled steel tube. The distance between axes of the branches is 5000 mm, and between axes of the crossbars is 6025 mm. As a result of calculation it was taken the pipe of diameter 820 mm at thickness of wallside 8 mm for branches, and for the cross-bars it was taken a pipe of diameter 530 mm at thickness of wallside 8 mm. The depth of the bearing with the head of bearing is more then 15 m. Heads of bearings were used from welding double-T. The members of the bearings were used beforehand. The bearings were erected on building ground. The branches of the bearings were placed at first turn. After that the branches were joined to the crossbars by immediate of adjoining (not fashioned joint) on welding, but the opening, witch was cut out in the wallside of the bearing, were equal to diameter of the cross bar.

For filling the dimensional system, which consist of struts and cross bars, it was used the pressure head concreting from below. For this the openings were cut out in bottom part of the strut and welded on the branch pipes, which were welded on after the termination of concreting.

It was interesting to know about the experience of use the concrete filled steel tube at reinforcement foundations of public and domestic buildings in Krivoy Rog. The irregular settings of foundations happens at the exploitation of the administrative building because of rising the groundwater level .

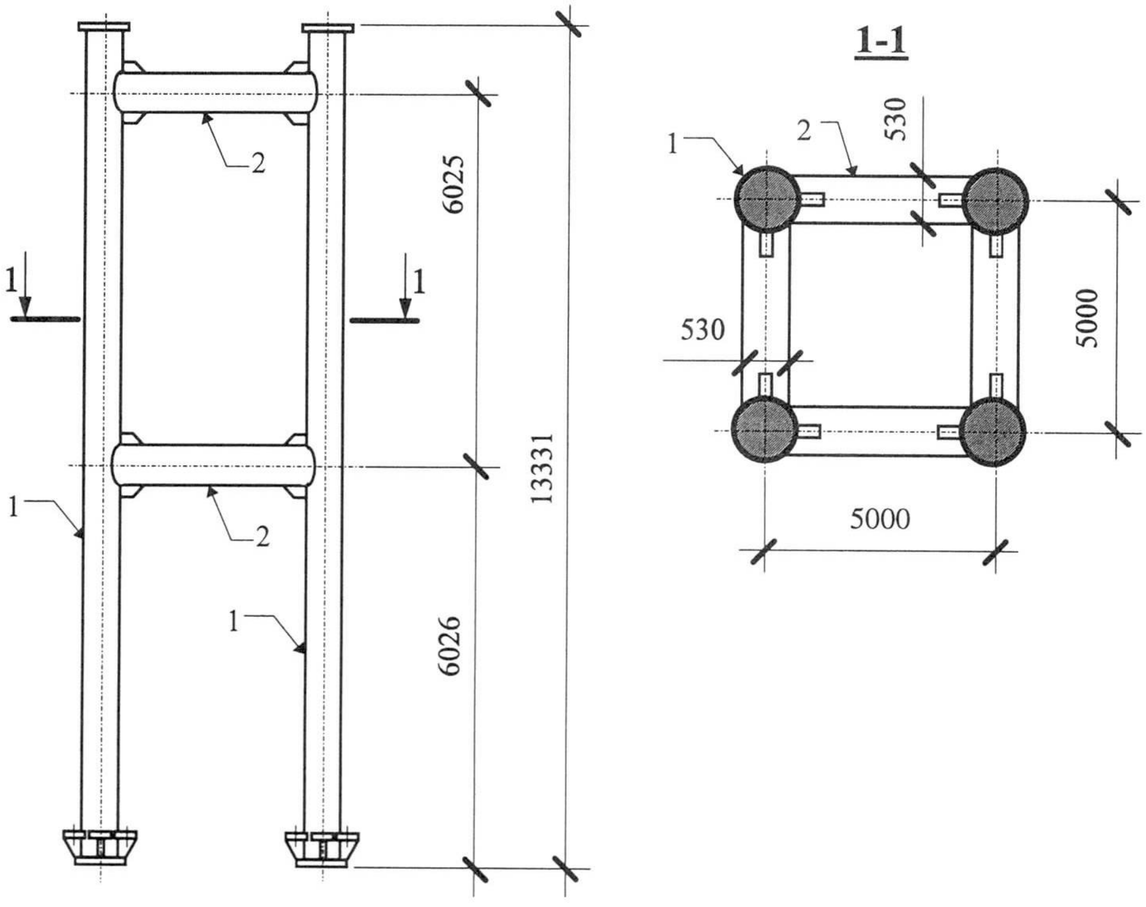

Fig. 1 Bearing of the transport gallery: 1 - strut; 2 - cross-bar

As a result of the prospecting, it was revealed, that foundations lead on the loess settling ground, which thickness was about 6 m. The underlying stratum under loams is the dense red-brown clay. At the moment of building the groundwater level was on the depth before 7 m from surface of the earth, but now the water level is on the depth before 2 m.

Some Procedures for Concrete Rehabilitation

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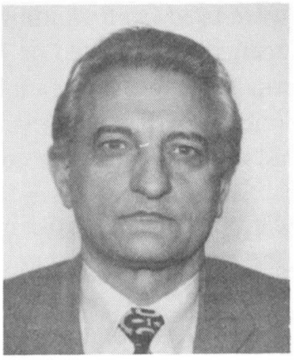

Corneliu Bob, born 1939, received his civil engineering degree from University "Politehnica" of Timisoara in 1962 and PhD in 1970. He is currently professor of Reinforced Concrete Structures and head of the National Research Institute INCERC- Timisoara branch. He published many papers and some books on various aspects of civil engineering.

Summary

The paper presents the deterioration of the different reinforced and prestressed concrete elements, the causes of deterioration and the procedures for rehabilitation. The existing buildings with reinforced concrete structures analyzed in the paper are: inside of cloak rooms (reinforced beams, reinforced strips); industrial hall (columns and foundations); inside of a textile factory (prestressed beams, strip with hollows, open caissons); water tower (conical roof); ground beam for travelling crane; bridges, power-line towers.

1. Introduction

The necessity to maintain and preserve the existing reinforced concrete structures in Romania is recognized, mainly, as economic good sense. This reason is due to the great number of such structures and of the low quality of concrete in some of the existing reinforced concrete structures. The durability of concrete structures depends both on the resistance of the concrete against physical and chemical attack and on its ability to protect embed steel reinforcement against corrosion.

During the last years the author has examined a lot of reinforced concrete structures with different durations of service life and some deteriorations of component parts. The deterioration of the reinforced concrete elements, the causes of degradation and specific procedures are presented.

2. Procedures for concrete rehabilitation

The procedures for concrete rehabilitation have been chosen in function of the causes of deterioration, the position of the elements in the structure, the detailing of elements, the available technology, the cost of rehabilitation etc. The main used procedures for reinforced concrete elements are presented below.

Cloak room elements. The deterioration causes of the reinforced beams and strips are: the presence of the intermittent humidity (RH>75%) and low quality concrete (17.5 N/mm^2 for the reinforced beams and 15.3 N/mm^2 for the reinforced strips). After 23 years of using, the carbonation depth was over 40 mm, from both theoretical and experimental determinations; the corrosion of main reinforcement was observed on a large area of the cross section. The methods of rehabilitation used for the beams and strips are presented . The strengthening consists in using the new reinforcements placed on the bottom part: close and welded at the two ends to the old reinforcement for the reinforced strip; space lattice with new stirrups for the reinforced beams.

Industrial hall has presented serious deterioration at the inferior part of the reinforced concrete columns which have had the main reinforcement corroded due to the intermittent humidity. On the other hand the structure was not well designed to the seismic actions in the transversal direction. The rehabilitation consists in erection of new reinforced concrete frameworks with bigger side spans and in the repairing of the former columns placed between the new frameworks.

Textile factory was examined due to special conditions existing inside the hall: intermittent and high humidity, presence of chlor ions, high temperature. Three structural elements have been investigated: prestressed beams, strips with hollows and open caissons. From these elements only open caissons have presented a serious corrosion of main reinforcement caused by actions of both carbonation and chloride penetration. New types of open caissons with high quality of concrete and bigger concrete cover have been used instead of the damaged elements.

Water tower is of 500 m^3. The reinforcement in the radial direction of the conical roof has presented significant corrosion due to: insufficient concrete cover and high humidity. The final solution, chosen for rehabilitation, was the use of eight pairs of channel iron profiles U of 120 mm (the height of the cross section). These profiles have to prevent the development of the possible yield lines caused by the positive bending moment in the conical roof.

Ground beams for travelling crane have presented very dangerous soil settlement (0 to 400 mm) under the weight of coal storage and travelling crane. The strengthening has been performed by erection of two types of over concreting with variable height and reinforcement.

Other elements as bridges, water cooling towers, power-line towers have been examined and specific procedures of rehabilitation were proposed. The reinforced concrete beams of an 80 years old bridge in Timisoara were also tested. The corrosion of the reinforcing steel was very large so that the strength and rigidity of the bridge beams were much diminished; this bridge was demolished and rebuilt. Some prestressed concrete columns, used for open-air transmission line, were fractured after a few years of use because of reinforcement corrosion: low quality of concrete and insufficient concrete cover. New power-line towers have been used.

3. Conclusions

The procedures for the concrete rehabilitation have to follow two main steps:

- The first step is a theoretical and/or experimental analysis for obtaining the data concerning the nature and the magnitude of the damages existing into the elements of a structure.
- The choice of the rehabilitation design for the building structure in order to obtain a low cost, good safety and durability, available technology etc. is an engineers main duty.

Structural Rehabilitation of an Industrial Steel Building

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Summary

The industrial steel building analyzed in the paper was constructed in 1967 and has been exploited in an aggressive atmosphere for about 25 years. The electrochemical corrosion occurred at the surface of the steel elements which together with design, construction and maintenance faults have significantly decreased the loadbearing capabilities of each structural member. The technical state of the structural system has been evaluated using visual inspection and nondestructive testing. Suitable strengthening and rehabilitation solutions have been proposed in order to restore the functional and structural performances of the industrial steel building.

1. The anatomy of the industrial building

The industrial building designated to shelter a zinc coated, cold-formed light gauge sections workshop has been designed and constructed between 1965 and 1967.
The framing system consists of ten main transverse steel frames, each of 3x24 m span (fig.1). The spacing between frames is 12 m. Seven overhead traveling cranes with handling loads of 125 kN to 500 kN are operating inside the building and transmit their load effects to the main structural system. Continuous tapered solid web welded sections have been selected for the main girders of the transverse frames. The main girders are supported on steel stepped built-up welded columns. The roof decking is made of prefabricated concrete elements which support thermal insulation and waterproofing. The roof decking is sustained by solid web welded purlins rigidly connected to the main transverse girders. The painting system applied on the steel members surfaces consisted of two main components: two layers of red-lead primer and two coats of chlor-rubber based paint.

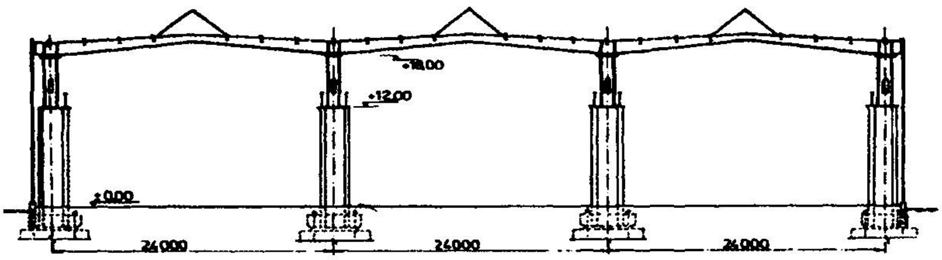


Fig.1 The transverse frame of the industrial steel building

2. The corrosive effects on the structural steel members

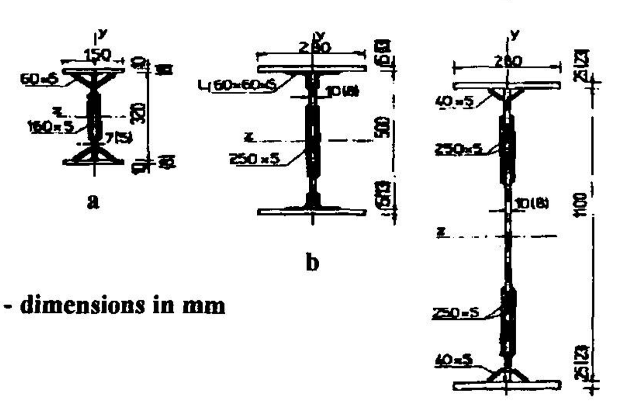
The structural steel members were exploited in a very aggressive environment (involving the use of sulfuric acid, chlorine hydride and hot water) between 1967 and 1980 and in a less corrosive atmosphere until 1992. All structural steel members have been severely affected by the corrosion process. Depending on the type of the element, the stress level and the local corrosive factors, extensive damages of the protective coatings, from 7% to 100% have been identified and corrosion penetrations up to 1.5 mm have been determined.

3. The influence of the corrosion on the loadbearing elements capacities of the structural members

The verification procedures for ultimate limit states and for serviceability limit states have been applied according to the Romanian Standard STAS 10108/0, and to the Code P-100-92, for design of structures in seismic zones. To assess the corrosion effect on the loadbearing capacity of the structural steel members the initial geometric characteristics (A_o=the noncorroded initial area and W_o=the noncorroded initial section modulus) have been compared with the same properties after exploitation in corrosive atmosphere (A_c=the corroded cross-sectional area and W_c=the section modulus of the corroded structural members). The numerical values of the deterioration ratios have been calculated for all main structural members as follows: purlins, W_c/W_o = 0.785; crane girders, W_c/W_o = 0.912; columns, W_c/W_o = 0.789 and A_c/A_o = 0.820; frame girders, W_c/W_o = 0.823 at midspan, and W_c/W_o = 0.901 on columns.

4. Retrofitting solutions

To restore the initial loadbearing capacity of the steel members, the strengthening solutions presented in figs.2 and 3, have been proposed. The strengthening pieces illustrated by dashed areas have been attached to the weakened members after careful cleaning of the corroded elements. The dimensions given in the parenthesis correspond to the corroded areas. After consolidation the ratios between the strengthened sections characteristics (W_1, A_1) and the initial ones (W_o, A_o) have been calculated: purlins, W_1/W_o = 1.03; columns, W_1/W_o = 1.04 and A_1/A_o = 1.02; frame girders, W_1/W_o = 1.08 at midspan, and W_1/W_o = 1.02 on columns.
The complete project of the structural and functional rehabilitation of this industrial steel building also implied: closing the space between the individual components of the compound bars; replacement of the deteriorated unsafe elements of the bracing system; concrete encasement of the column steel bases and of the lower steel column portions in the working areas with high humidities; remaking of the corrosion protective system on the steel members surfaces; improving the ventilation conditions inside the industrial building; observing the periodical maintenance cycles and the current repairs; reducing the atmospheric agressivity by blocking the pollutants at source; cleaning the industrial dust from the roof at least once a year; systematic observation and periodic inspection of all structural and nonstructural building elements.
The authors of the project and the owner consider that the proposed set of actions would extend the service life of this industrial building to a convenient period and at an acceptable cost.



- dimensions in mm

Fig.2 Strengthening solutions of bent elements: a-purlins; b&c-tapered frame girders

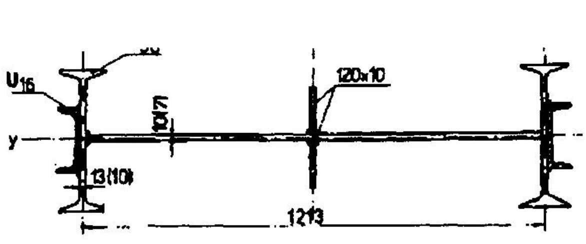


Fig.3 Cross-section strengthening of the main steel columns

Repair and Modernisation of Butt Joints in Enclosing Constructions

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Summary

In this work described technical concepts on the repair and modernization of butt joints and their elements in enclosing constructions with the help of magnetic materials and magnetic pseudo-fluids (such as magnetic paste, powder and fluid). There is also given the results of testing and showed the advantages of these technical concepts in comparison with the traditional.

In the NDIBC of Ukrainian urban building state committee there are elaborated and tested constructive decisions, could widely developed in a repair, especially on the constructions of inicial house - building period.These decisions touched on window's, and door's apertures canning, reinforced construction joints, sectional houses and container-houses. They have certificated and patended.

The butt joints canning with magnetic materials are realized by the sealing gasket installation in a gap. The gaskets close magnetic field in a whole joint length or in a gap perimeter after the consequent gap containing with a magnetic pseudo-fluid (MPF).

MPF is a very dispersed material in a state of paste, powder or fluid. It is prepared on the base of material, connected with magnetic phase by essential adhesion interaction: bor nitride, molybdenum diselenide, graphite. MPF reduces pore sizes because of their optimum consists in 0.05 - 0.1mm. The water - repellence of MPF ensures repulsion of a moisture.

The magnetic attraction takes preference over the gravitation more than one order, it allows for MPF to be on the magnetic material surface.

For example, in wooden window or door, having an old design, could sealed off, it would for such technical decision been executed. On one of the door-frame or window-frame surface a magnetic circuit material could be fixed normally to this surface with the a projection above it. In the same time these have foresaw recess on the door or window linen, that docks complactly with a corresponding frame. A magnetic-elast is fastened on both sides of recess, having function of a magnetic field steam. MPF has put over magnetic-elast in a created clearance.

If a door linen or a window leaf has came through, the magnetic circuits, fastened in its perimeter, having been joined themselves on the same surface. So, a magnetic field has been closed by this way. The aperture sealing has taken place as a result of it. MPF hasn't been removed because of its deeping.

There are passed bult butt joints of the guard structures and their fragments study, that sealed off according to proposed technical decision. In comparison with widely extended sealing gaskets (wool, polyurethane foam, sponge rubber and others) magnetic gaskets have prevalences in specific waste of heat (0.14-0.59 Wt/sm^3) and laweringof air - penetration more than five times.

So butt joints canning in a guard structure or in a window's aperture or in a door's aperture with the help of magnetic materials and MPF allows heat qualities for bettering and air-penetrability for lawering. Its result is economy of the fuel-heat resources.

The magnetic materials and MPF can be explored in the wide diapason of temperature - from 70 to 700 K in the simultaneous preserving of their physical and mechanical properties. They have a long term of action (demagnetizing consists 0.01% per year). These materials aren't toxical owing to their nature, they have slight cost. Every MPF has high elasticity and quickly recovers after breacking of wholity.

The NDIBC has elaborated albums of the technical decisions in the guard structures and their parts canning with the help of magnetic materials and MPF, the methodical recommendances in their producing and inculcation, the program in magnetic field computation before giving magnetic properties for materials.

Use of Basaltic Fibers in Concrete and Thermal Insulation

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Summary

The basaltic fibrous concrete represents wide group of new building materials consisting of concrete and basaltic fibers in the form of artificial threads of different diameter and length(among others in the form of bar reinforcement).The theoretical and experimental researches let us to conclusion, that structural elements (such as wall panels, slabs, partition elements etc.) of basaltic fibrous concrete are much stronger, more stable for aggressive force, lighter and more effective for producing than the traditional ones. It is possible on the basis of results of express-analysis methods to say, that durability of basaltic fibrous concrete structures surpasses of traditional ones.

Keywords: basalt, fiber, reinforcement, concrete, thermal insulation, effective, structure, composite, material, technology.

1. Introduction

Now it is well known many various methods of dispersed (fiber) reinforcing of concrete in the building field. Among others the reinforcing of concrete with steel wire pieces of different diameter and length is particular popular. As a reinforcing agent are also used the unbroken glass fibers. But the development of production of such concrete is delayed mainly because of the increasing lack of materials for glass fibers. And here is given results of researches of dispersed and with unbroken bar reinforced concrete structural elements, in which basaltic fibers were used as a reinforcing agent.

2. Modification of Reinforcing Basaltic Fibers

A short list of qualities of basaltic fibers and products made of them is following:

- stableness for corrosion (12-5 times more than metals);
- frost- and heat-resistance (-265 C, +900 C), non-toxic;
- high durability showings (1900-2400 MPa when diameter of a fiber is 9-12 mcm);
- construction elements are sometimes 3-10 times stronger, than analogous traditional constructions made of steel and concrete;
- lightness (decrease the weight of construction elements 5-20 times);
- do not create hindrance for radio and television waves and are dielectrics;

- heightened water-resistance;
- when fibers are received as mineral wool, meet the requirements to be raised to heat-insulating materials.

There are modifications of basaltic fibers used for reinforcing of concrete in our experimental work:

- bundled basaltic threads, which were saturated with polymer bonding adhesive (basaltic plastic reinforcement in the form of bar);
- basaltic rough fibers (0.18-0.20 mm in diameter and 20-25 mm in length);
- basaltic "stapel" fibers which are bundled from 200 pieces of threads of 0.009-0.012 mm in diameter and 35-50 mm in length.

3. Research about Anchorage Basaltic Fibers in Concrete

Determining of effects from using basaltic fibers for reinforcing of concrete requires to answer a question, how effectively does different variations (modifications) of basaltic fibers anchor in concrete body.

The rules of distributions displacement(U), of stress level(F) and of tension(t),applied on different examples anchored in concrete, had been got on the basis of theoretical and experimental modeling.

It is also interesting to determine the anchorage length and displacement for different kinds of bar reinforcement, anchored in concrete constructions of various strength. Leaning upon results of experimental and mathematical modeling, which were executed for different force application on anchored bars, had been made conclusion, that displacement of bar reinforcement of various kind (of basaltic plastic, of glass plastic and of steel) can be calculated with using the following formula:

$$U_z = \frac{N}{3F\{E_1/[(1-2\nu_1)L_1] + E_2/[(1-2\nu_2)L_2]\}},$$

in which:

N - the force applied by the bar reinforcement;
U_z - the displacement of bar at the place of force application;
F - the cross-section-area, filled in with mortar, between yoke (fuxture) and bar;
ν_1 - Poisson's ratio for first mortar;
ν_2 - same for second mortar;
E_1 - modulus of elasticity for first mortar;
E_2 - same for second mortar;
L_1 - anchorage length of bar in first mortar;
L_2 - same in second mortar.