Methods of Surveying Dubrovnik's Architectural Heritage*

Svetislav Vučenović

'The contents of this paper represent an attempt to put forward systematically, various kinds of experience and their adaptation to the urban entity that is Dubrovnik and the circumstances in which restoration work is being carried out. The views and the recommendations advanced here are tentative and open to suggestions and supplementation. This approach which issues from a collective body of knowledge may well serve the general evolution of practice. Conversely, the practical implementation and testing of the methodological approach will make a contribution to its improvement. This mutual influence as between theoretical principles and operational practice will ensure that experience gained in Dubrovnik constitutes a valuable contribution to our contemporary code of practice dealing with the conservation of our cultural heritage. Dubrovnik's status as an item in the UNESCO Register places this obligation upon us.'

1. Study of archival material

One of the great advantages Dubrovnik has over similar old towns is an abundance of well-preserved archival material both from the period of the Republic and the past two centuries. This inexhaustible source of information about many areas of life, especially about building, demolition and renewal in the city, is enormously important for restoration work because it provides a valuable supplement to field data and findings arrived at by researchers.

Like all other constituent parts of this large-scale project, the study of archival material must serve a double purpose: it should make a scholarly contribution to our knowledge of Dubrovnik's architectural past and also play a practical role in its conservation and renewal. In order to accomplish this dual purpose, the role of archivists, historians and researchers must be adapted to the needs of field work, because applied research is of greatest benefit when it is incorporated into conservation guidelines and projects. It is therefore very important to synchronize archival and field work. Unless this happens, the chance to involve archival material as one of the most vital factors in the evaluation and management of the architectural heritage will diminish or even disappear.

In the context of this comprehensive project for the urban renewal of Dobrovnik, which will extend over a number of years, research into the archives can, and indeed must, play an active part and should be allocated a certain degree of priority. It is therefore essential to set clear goals, to identify the participants, to draw up a timetable and to secure the necessary funds from the resources of the urban renewal campaign which is already under way.

2. Technical specification

Adequate, precise and up-to-date technical specification is the basis for all stages of the project, including preliminary research, surveying and the actual execution of the work. In contemporary practice a variety of methods are used, depending on field conditions, the purpose of the project and its application.

In addition to conventional surveying methods, aerial and terrestrial photogrammetry are also used, the former for preparing area maps and maps of settlements, the latter for mapping groups of buildings, elevations, interiors, façades and internal decorative features. In addition to graphic presentations, numerical data on distortion, tilt, sinking and other changes in the original structural geometry may be obtained. Such data are very important in structural stabilization plans, because they provide precise information on the degree of tilt from the vertical alignment and the original floor or structural levels.

In addition to these surveying methods, architectural drawings of the ground plan, façade sections and details based on field sketches and detailed measurements are also widely used.

These methods will be combined in practice and such new ones adopted as the best suited to the specific project. Such a synthesis of methods is most often needed in planning the repair of complex historic buildings -- churches, palaces and fortresses.

In view of the scale and duration of the Dubrovnik restoration project, it would be advantageous to centralize work on technical documentation. This would make it

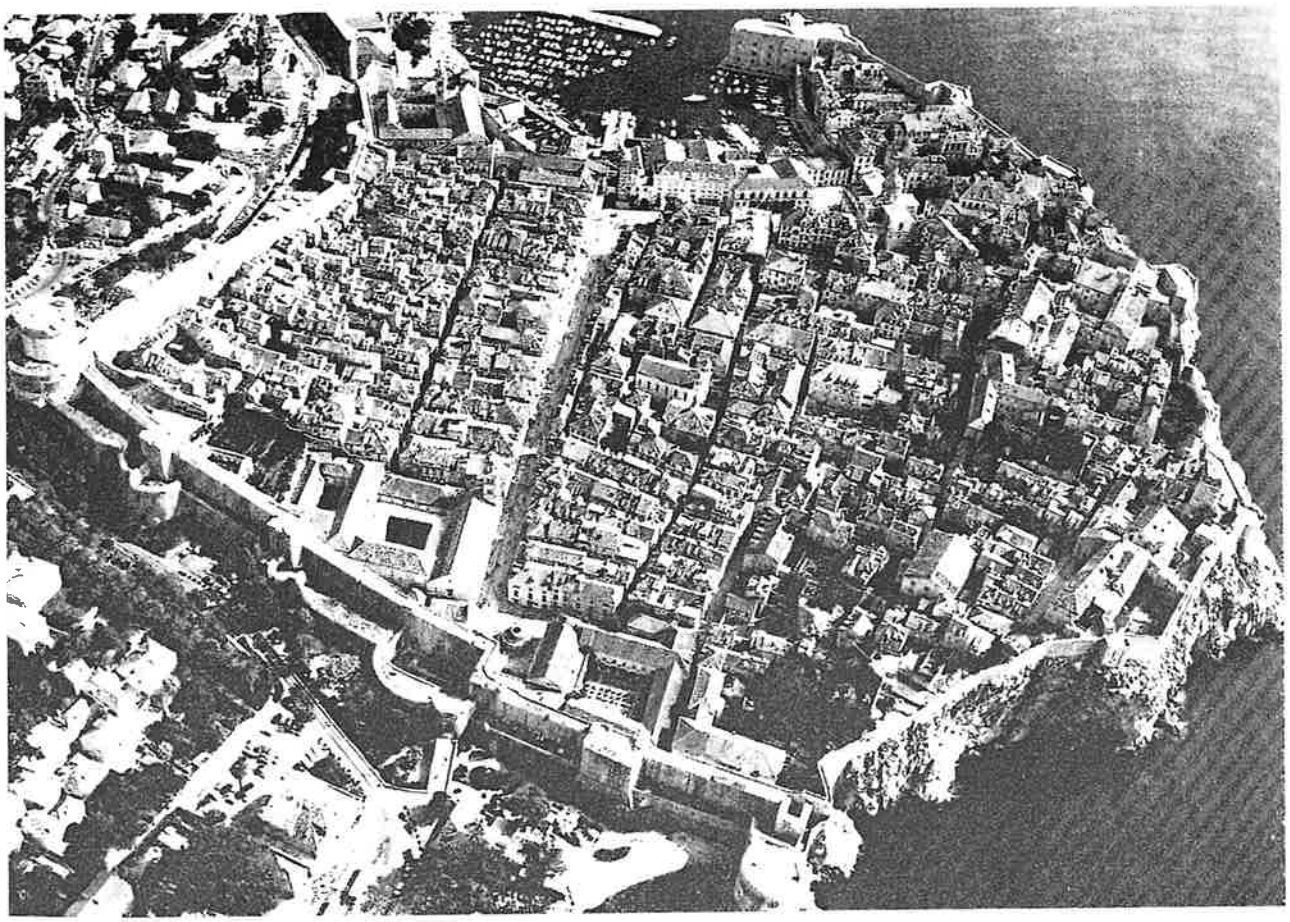

Fig. 1. The City from the West (Mato Novakovie) Dubrovnik

Fig. 2. Arcades of Sponza Palace (Nenad Gattin)

possible to achieve uniform standards, reduce investment and coordinate the work of the experts preparing the documentation and of those using it.

3. The preparation of surveys

Information on the history of the buildings, their structure, the state of repair of the materials, decorative work and the like is collected by means of field analyses of the existing situation. This is usually done in three stages:

1. *Collecting the directly accessible data on the façades or in the interior of the buildings, which will provide a general picture of the state of the building.* This primary evidence will be collected for all buildings regardless of their historic status. The end of this stage consists in determining the problems that have to be studied in depth, for instance by test boring and the removal of more recent layers. This part of the survey is usually conducted jointly on all the buildings covered by the project; the survey may also be undertaken separately for different parts of the city. The data can be used for making inferences on the level of the agglomeration, for preparing graphics on layout drawings and town plans.

2. *Collecting additional data concerning the structure found in the deeper layers, under the plaster, in the structures, foundations, etc; test borings on walls, roof-beams, foundations; identifying the different layers of plaster on the façades and interiors with fragments of mouldings or painted ornament.* These studies are concerned with many problems but are conducted on strictly delimited areas and small samples and resemble laboratory tests rather than tests on a building site. They can therefore be conducted in occupied buildings since they do not interfere with their functioning. This exploratory stage will provide data for conservation guidelines and preliminary sketches.

3. *Complex investigation of the historic building using architectural heritage methods.* This can be undertaken only when the building has been vacated of all its users. It must be organized as a building site on the basis of a detailed plan of exploratory and preliminary work with clearly defined objectives and scope of work. The aim of the exploratory component is to furnish all the relevant data that were inaccessible in the occupied building. The preliminary work will include the removal of sterile layers, fills, subsequent linings and layers of plaster, i.e. all those elements that are no longer needed in the building. These operations may be on a very large scale and require building machinery and the removal of debris. When the historic building has been stripped to its bare structure, it is possible to explore the state of repair of materials, structural stability, deformations and the settling of cracks. The building can now be explored in terms of all the data needed by historians, archaeologists, conservationists, architects, civil engineers, restoration specialists and other experts participating in the project.

This research is aimed at obtaining the following information: a detailed life history of the building; a list of conservation requirements, accompanied if necessary, by graphics; a detailed analysis of the state of repair of the materials and structures with a plan for their restoration; a detailed description of the planned functions versus the restored historic complex; detailed conservation guidelines and requirements, which will be used in preparing the master plans for restoration and conversion.

4. Conservation guidelines (requirements)

The Agency for the Protection of the Cultural and Natural Heritage of Dubrovnik is responsible for defining the conservation guidelines (requirements) for restoration work on protected properties and historic complexes.

In keeping with legal regulations, conservation methods and established practice, the guidelines are issued after the completion of surveys which include the following: archival material, sources and literature; the preparation of technical documentation (with a full photographic record) about the state of repair of the building; the history of the building including the original design and the subsequent alterations; a study of the building's traditional use versus its planned use; specifications and constraints for the incorporation of seismic and other types of reinforcement; interior and exterior architecture; other questions relating to the features of the historic structure, its state of repair and the renewal programme.

The comprehensiveness and degree of detail in the conservation specification depend on the accessibility of the property concerned. The best situation for comprehensive and detailed exploration of the building will be created if it is vacated by all its occupants.

However, it frequently happens in practice that the resettlement (temporary or permanent) of the occupants can be carried out only a short time before the start of the actual restoration work, due to difficulties in settling property rights and legal considerations, financial and technical reasons and other obstacles which crop up in the course of the work. In such a situation, the investigation and preliminary work for the survey and conservation specifications will have to be done in several stages. The first (with the occupants still in the building) may include partial exploration, which will serve as a basis for the general outline of conservation specifications. This second stage will be undertaken in the empty building and will include all the elements described earlier.

The circumstances in which the investigations for preparing the survey are carried out may lead to misunderstandings. Clients or their agents expect the conservation specifications to be prepared on time and in definitive form regardless of whether or not the building is accessible to the surveyors. These unreasonable expectations may be avoided by specifying in the preliminary guidelines whether the building is to be partially or totally evacuated before the survey is undertaken.

In view of the current practice and attitudes of the responsible authorities in Dubrovnik, it is reasonable to expect that surveys will have to be carried out in two stages in most buildings. In this case the following rule will apply: the conservation requirements resulting from the first stage of the survey will be used for preparing preliminary

restoration and renewal plans; in preparing master plans conservation requirements based on a revision of the preliminary scheme will be used. The issue of detailed requirements must be preceeded by a thorough survey of the unoccupied premises; whether it will be vacated immediately and totally or whether the survey will be carried out in stages depends on the type of problem presented by the building itself. The final decision on this rests with the Agency for the Protection of the Cultural and Natural Heritage of Dubrovnik, which will base it on the findings and opinions of the responsible surveyors.

Practical experience in restoration work in many cities similar to Dubrovnik would suggest the following: conservation guidelines are the prerequisite for the conservation project documents. Attempts on the part of some participants in the renewal project to postpone part of the exploration work necessary for the surveys and carry it out when the investment documents have already been completed and the actual restoration work is under way should be eliminated from practice. They lead to clashes among various interested parties, unnecessary delays in the execution of the work and may put at risk the historic characteristics of the property. Once the investment process has got under way, only those sites that could not be researched without construction plans because of their location (great depth, archaeological finds, overburden in the form of large amounts of building martial, etc.) will remain to be opened up. To these should be added unexpected finds in the subsoil or the debris, soil profiles in open pits, movable fittings, etc.

As is generally the case in restoration work on historic monuments, the research function and supervision by conservators will continue until the completion of the project. It therefore follows that some of the conservation specifications may be changed while the work is under way. The changes will depend on the type and importance of new findings which in their turn will be fewer in number and will have a lesser influence on the development of the work if all the necessary research was done before the preparation of the project plans. There have been cases in current practice in which the procedure went the other way round: the master plans, including those for structural stabilisation, were prepared for premises which were still fully occupied, and before a thorough survey had been

Fig. 3. The Fortress of Lovrjenac (Nenad Gattin)

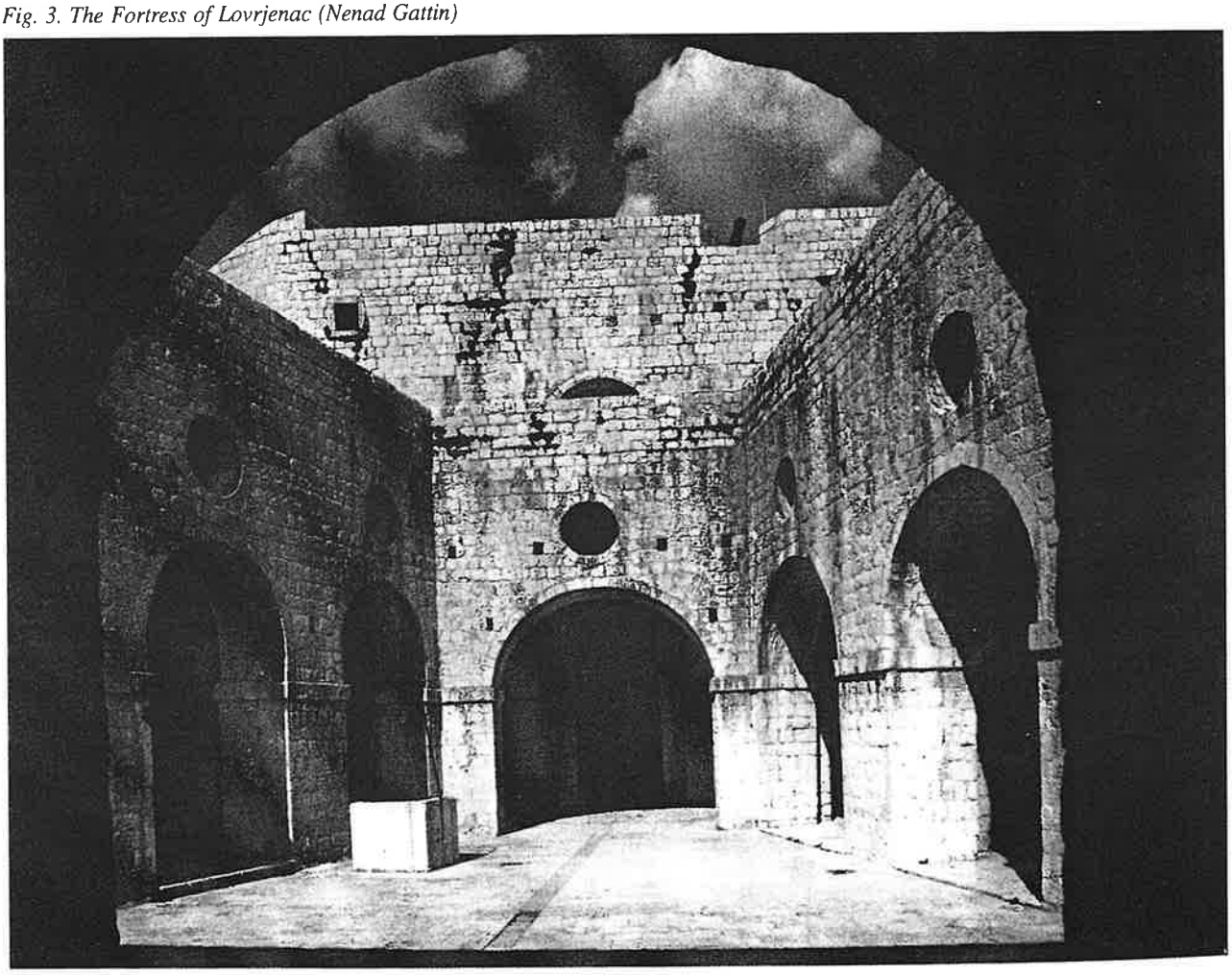

Fig. 4. (Nenad Gattin)

carried out. The haste involved here produces a very real risk that the realisation of the true state of affairs may require changes in the plan of operations. It is even quite possible that the amount of new data will be such as to impose the need for a new plan. Seismic reinforcement is a case in point, because the depth and width of the footings, subsoil composition, creaks and decaying walls are discovered only when work on the repair of the building has already begun. New data on the origins of the building, its original architecture and ornamentation will inevitably appear, imposing their own requirements.

In the technological sequence of procedures in a historic monument, the preparation of conservation requirements has a well defined place and role. Any deviation from conventional and established methods at the very beginning of the project will hamper and delay the later stages of the project. It is therefore in the best interests of all the parties concerned that a detailed survey be carried out at a stage and on a scale indicated by the project as a whole and not when it suits individual participants.

Svetislav Vučenović

5. Conservation requirements for works on protected historic buildings

I SURVEY

1. *History of the Building*

   Historical data on construction. Investors. Contractors. Architectural style. Original design. Construction stages. Typological characteristics. Analogies.

2. *Design*

   Layout. Location within the town. Neighbouring buildings. Orientation.

   Ensemble. Main building, adjoining buildings. Courtyard, garden, grounds.

   Number of floors. Layout of premises. Communication.

3. *Use*

   Original use. Later uses.
   Current use. Layout by floors.
   Services. Surviving part of old services. Cistern.
   Drinking water.

4. *Materials - Structures*

   Loadbearing walls. Joists. Vaults. Roof. Staircase.
   Wear of the materials. Causes of decay.
   Weak and damaged structures. Deformations, cracks, crumbling.

5. *Interior*

   Interior finish. Floors, walls, ceilings, vaults.
   Surviving stylistic features or their fragments.
   Possible existence of original finishes underneath later layers.

6. *Exterior*

   Layout of façades. Shape of apertures. Masonry techniques. Mouldings.
   Changes of the original design. New openings.
   Plastering. Roofing. Eaves. Stone gutters. Old chimneys.

7. *Surroundings*

   Courtyard. Paving. Well-heads.
   Garden Pergolas. Mature trees. Shrubbery.
   Natural soil. Rocks. Wild growth.

8. *Documents*

   Archival data. Basic literature.
   Survey. Photographs.
   Plans. Construction records.

II CONSERVATION

1. *Evaluation*

   Cultural and historical significance. Architectural qualities.
   Features detracting from the value of the structure.
   Categorization: cultural monument, a stylistic and ambiental complex.

2. *Project Schedule*

   Characteristics and features of the complex that have to be permanently protected.
   Inferior conversions to be removed.
   Reconstruction work, if any.

3. *Conversion*

   Spatial possibilities of use. Suitable uses. Permitted scope of alterations in the interior layout.
   Requirements and constraints.

4. *Repair*

   Old structures that have to be preserved. Reinforcement.
   Conservation and renewal of building materials.
   Insulation.
   Seismic strengthening requirements.

5. *Restoration of the interior*

   Stylistic features that have to be conserved.
   Elements of the interior that have to be preserved.
   Restoration specifications.

6. *Restoration of Façades*

   Original patterns and elements that have to be preserved.
   Removal of inferior conversions and recent apertures.
   Discovery and repair of period architectural features.

7. *Area arrangement*

   Ambiental characteristics that have to be conserved.
   Inferior adjuncts that have to be demolished.
   Possible interventions in the surrounding area and vacant sites.

8. *Works schedule*

   Research: field, archival.
   Survey, photographs.
   Design stages.

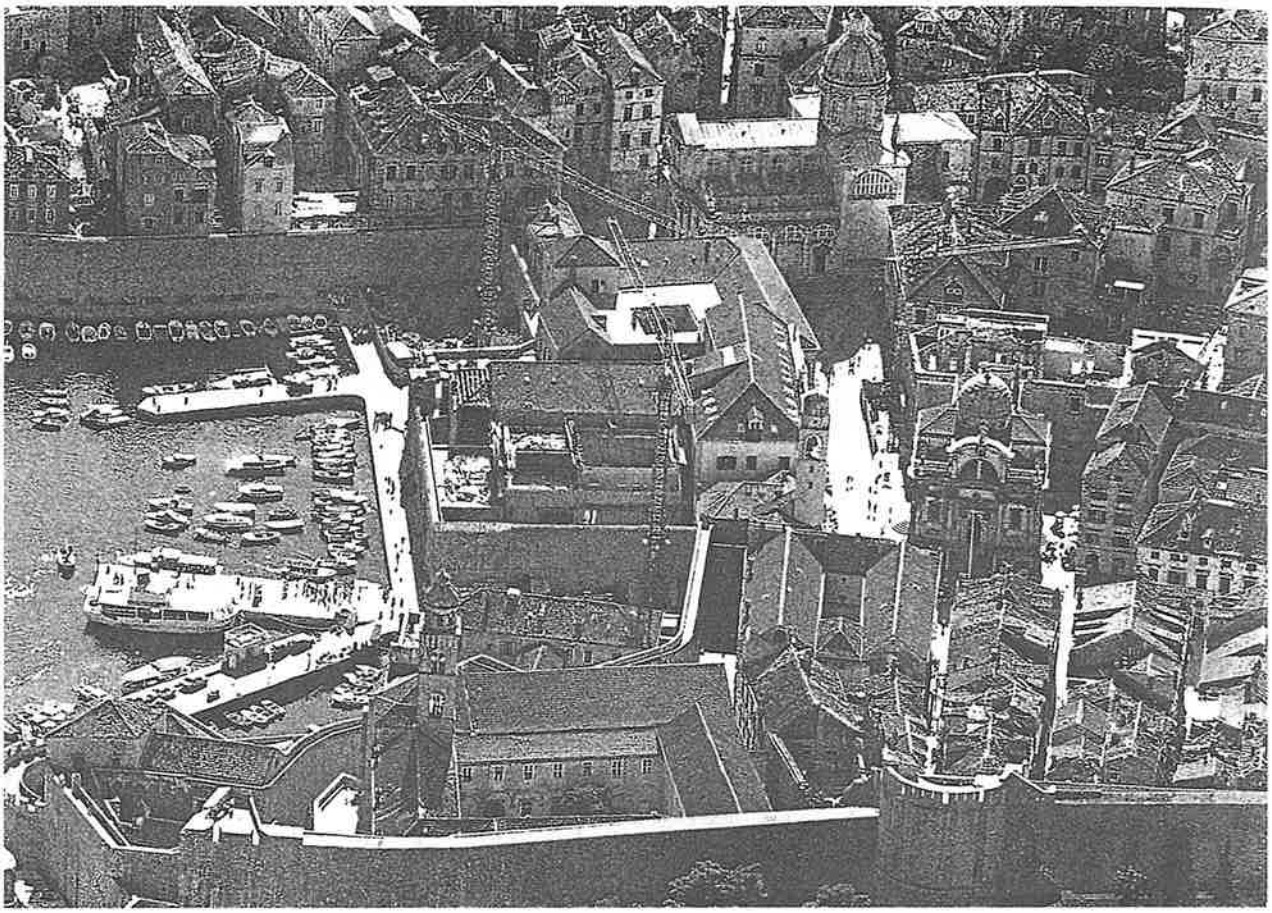

Fig. 5. The eastern part of city from the harbour (Kresimir Tadic)

6. Principles of conservation

The preparation of conservation specifications involves many issues and problems. Out of this long list we propose to describe the most complex and frequent tasks facing the conservator: traditional architecture versus modern uses; ancient stone structures and modern repair methods; ways of preventing dampness in historic buildings; conservation of stone façades; roofing materials, etc.

By comparing and analyzing various approaches and procedures, the conservator will arrive at methods that are best suited to the specific characteristics of the architectural heritage. Conservation practice in Dubrovnik has reached a high professional level in some area, while in others better solutions must be found. A valuable help in this search is the positive and negative experience gained in other, similar projects, for it is by identifying the pitfalls of an undertaking that we can best avoid them .This is why we propose to pay special attention to the latter here.

Conversion

The comprehensive urban renewal scheme now under way in Dubrovnik includes not only the restoration and repair of properties, but also changes in their use, a re-organization of the available space and the modernization of services.

Under the provisions of the implementational town plan, many buildings will be used for a different purpose; there will also be a change in residential versus commercial use. In many buildings, especially older ones, the original layout has suffered many alterations in the course of time. With changing ownership or tenancy, reconstructions were undertaken that altered, damaged or destroyed the original layout and interior architecture. . Major social and demographic changes led to the division of original family houses into flats and of major public complexes into anonymous units.

One of the essential questions that arises in the context of architectural heritage conservation is whether historic buildings should be handed over to their future users in their present-day shape with the necessary adjustments to modern standards or whether they should be restored, as far as possible, to their original style. The answer to this question will significantly influence the objectives and programmes of the project.

What happens in practice is that projections of future solutions are often based on the existing situation, the one that everyone can see and not on the original architecture, which can be discovered only through research. Preliminary sketches, feasibility studies and other documents thus clash with potential solutions and the original architecture that emerges from research. In order to avoid this clash between the planned use and traditional use of the premises, as well as misunderstandings among participants in the project, the question of future uses should be subjected to the same procedure as all the other elements of the project. This means in practical terms that the implementational town

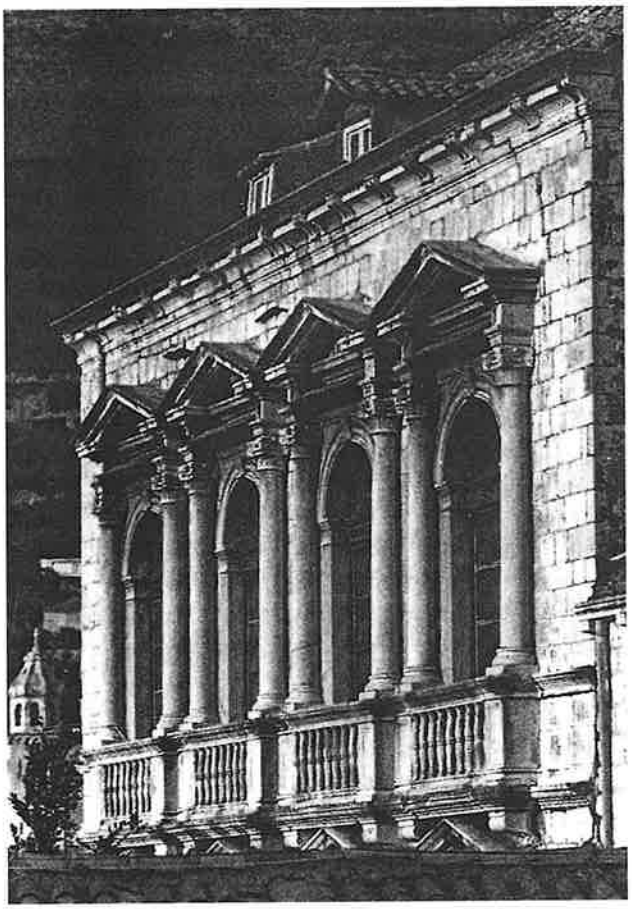

Fig. 6. (Nenad Gattin)

Fig. 7. (Nenad Gattin)

plan and investment studies should include the proposed use which will be approved or rejected after the necessary research has been carried out. In buildings of lesser historic value and in those which are simpler or chronologically more uniform, the initial ideas and final solutions may be identical or only slightly different. But in architecturally complex and very old buildings the differences may be so major that tentative schemes for future functions must ultimately be abandoned.

In order to obtain reliable answers to these questions the final restoration and repair plan must be preceded by careful studies of the building's history — its original architecture and subsequent alterations, some of which may be deemed worthy of protection. In buildings showing different architectural styles, a compromise solution which will not discriminate against particular periods will be sought. These studies should not be burdened with the preconceived idea of a proposed use but must be guided by independent criteria. A solution based on the proper balance between historical considerations and modern use will be beneficial for all parties concerned. This is the only acceptable formula for active protection of the architectural heritage, in which revitalization means much more than merely functionalism, because it fully rehabilitates the historical message and the architectural merit of the inherited buildings.

It goes without saying that this correct approach is often hampered by various obstacles, the most serious of which are ownership rights and leases and the oversimplified schemes adopted by investors. This is often compounded by lack of an adequate research effort on the part of some planners, whose solutions are nothing more than correct routine.

It is the established practices in Yugoslavia to entrust the responsible authorities with working out the conservation guidelines and to commission the technical and financial documentation from a registered consulting firm. However, experience gained in restoration projects elsewhere indicates the need for a different procedure, especially when complex historic buildings are involved. In such cases the project should start with plans for the restoration of historic architecture based on results of relevant studies and regardless of any proposed uses. It is only when conservation requirements and specifications have been prepared that the use of the building can be decided on. Project documentation produced in this way would fully reflect conservation requirements and could be used as the basis for further planning.

The next stage in planning is the examination of the restored building and its possible uses. At the preliminary design stage alternative potential functions are examined. The layout for the chosen function is designed at the master plan stage; however, when the proposed use involves complex technological solutions, alternative uses are proposed in preliminary design.

This procedure in more comprehensive and gradual, but, on the other hand, less subject to contradictions that

may slow down the work or lead to the rejection of the originally planned uses. In this conception the plan for the restoration of the architectural heritage plays a major role, because it forms the bridge between historians and conservators on the one hand and town planners and architects on the other. The importance and complexity of the architectural heritage makes the interaction and team work of many experts a necessity; indeed, it is only through team work that satisfactory results may be achieved. In such a formula, the results of preliminary research are expressed in the project and vice versa -- work on the project is at the same time on-going research.

Structural repair

Traditional structures made of stone are an integral part of the architectural heritage. Consequently, one of the basic requirements in projects involving the strengthening of historic buildings is the conservation of ancient structures, materials and technologies that reflect the experience and craftsmanship of old builders.

A considerable degree of reinforcement may be achieved by using original materials and techniques, in which the old elements are replaced by new ones, or by grouting damaged massive walls and vaults, replacing wooden joists, etc. Numerous examples of old stone-built houses show that buildings with sound structures can withstand earthquakes although they do not have seismic reinforcement, for instance tie beams or other types of strengthening available in modern building technology. Buildings in Dubrovnik which were repaired after the big earthquake of 1667 with iron anchors, by means of which the wooden joists were secured to thick walls, were thus given greater stability. At the same time, adjacent buildings with dilapidated structures and materials suffered damage or were even partially destroyed by the same seismic shocks. The same situation is found in other towns affected by earthquakes along the Adriatic coast. This shows that old stone buildings do not suffer damage in an earthquake mainly because of the way they were built but because of the dilapidated state of the materials and structures or because of soft subsoil. The passage of centuries and long-term exposure to the activity of various agents weaken the binding materials and structures. By contrast, some historic builds have shown an exceptional 'inherent' resistance to earthquakes, having withstood several earthquakes without suffering major damage. Dubrovnik has a number of such buildings including very valuable medieval and Renaissance complexes — monasteries, palaces, houses, parts of fortifications, etc.

This phenomenon has not received the attention it deserves. Questions about the resistance of conventional materials and structures to earthquake activity therefore remain without scientifically researched answers. The statics of historic buildings, a discipline that would fill many gaps in our knowledge and prevent many errors in conservation work, has been neglected by scientists and civil engineers alike. Dubrovnik offers an excellent opportunity for systematic research into historic structures, their classification, computerized model analysis, etc., because it has a large number of buildings dating from a wide range of architectural periods. The wealth of archival material makes it possible to study traditional building methods and techniques, while the repair work that is now under way provides a clinical picture of their application. This approach would produce benefits for theory and practice. Research into the history of structures would fill the considerable gaps that still exist in our knowledge about this feature of the architectural heritage. Findings based on a comparative analysis of many old buildings could be used as criteria for the strengthening of old stone structures. In such a context, the incorporation of new reinforced concrete elements would be reduced to the absolutely necessary minimum, i.e. it would be resorted to only in cases when the necessary resistance cannot be achieved by restoring the structural components to their original stability. There is a big difference in the same materials between the 'lower' resistance threshold of the old structure and the 'upper' threshold that can be achieved through restoration work. Although this can be observed in many buildings affected by the 1979 earthquake, many states stabilization plans prepared in the past few years disregard this fact. They place the main emphasis on new elements, which are often too heavy, bulky and difficult to build with. By repairing the original structures in the old buildings, the use of new structures could be reduced to the indispensable minimum. Examples of an erroneous approach to restoration work in areas outside Dubrovnik and the possibility that the same mistakes could be repeated in Dubrovnik show that we might be in the apparently paradoxical situation of having to protect historic buildings from excessive protection against earthquakes. It has to be emphasized that old structures are not only there to bear loads, but are also transmitters of building experience and of traditional crafts — they are, in fact, archives in stone. Architectural heritage conservation must therefore aim above all at developing and applying specific methods which will safeguard this function, such methods as will simultaneously retain the building's historical integrity and renew or improve its physical stability. Otherwise, measures designed solely to improve a building's stability may rob it of those features that constitute its historical interest. This would call into question the basic purpose of such work, which is to prolong the life of buildings as historic monuments and not their mere physical survival.

A comparative analysis of methods currently used in repairing historic buildings shows considerable differences in the approach to the architectural heritage threatened by seismic activity.

Seismic reinforcement methods

Among the methods used for the strengthening of historic stone buildings, the employment of reinforced gunite is the most questionable. It is usually applied as lining to one or both sides of a wall with clamps running through the entire thickness of the wall. Acting as a kind of steel-concrete cage, it completely blocks the load-bearing walls with their architectural features such as doorways, cornices, cantilevers, niches and sometimes painted decoration. The

Fig. 8. (Tomislav Kralj)

increased thickness of the walls upsets the equilibrium of the wall surfaces and other elements, some of which are inevitably destroyed in the process. Moreover, the reinforced gunite method is incompatible with the principle of reversibility, i.e. the possibility of removing the built-in reinforcement should the development of building techniques make it possible to strengthen the building by means of more suitable procedures.

Another method of repairing damaged buildings was widely resorted to after the 1979 earthquake in Montenegro. It consists in forming a reinforced concrete skeleton with joists, which are built into the body of the building, from which all partition walls and wooden joists have been removed. The element causing considerable difficulties and negative effects in this procedure is the corner column, i.e., the vertical tie beam. In order to build it in, a section of the wall larger than the beam itself must be pulled down at the corners, where the stone wall with its dove-tailed blocks is strongest.

A method by which these drawbacks can be avoided uses the following arrangement of reinforced concrete elements: reinforced concrete walls are built into the location of the previous, partition walls (or there abouts), along the axis of the building; together with the joists and the tie beams they form a rigid structure to which load-bearing walls are anchored. The old stone structure and the new reinforced concrete element are connected by means of partially buried tie beams and steel clamps which seare the façades. The old structures are strengthened by grouting, sealing of the damaged sections or partial reconstruction.

In the procedure described above, the new elements are aligned along the partition walls rather than the loadbearing walls. In this way, the thick main walls and all architectural features are left intact. The old and new structures are jointed in the same places as originally: at the joist level and along the partition wall lines. This reduces to the minimum the need for making junction slits. The method also makes it possible to find flexible solutions for the internal layout, taking into account both the original architecture of the building and its new use.

This method also recommends itself from the point of view of civil engineering physics and hygienic facilities. Instead of using a stone core packed in gunite, a reinforced concrete partition may be lined with composite materials in order to improve acoustic and heat proofing. Moreover, there is no need for a concrete lining on the internal side of the front walls, which tends to impair air circulation and increase condensation.

This method was successfully used in several buildings damaged by earthquake in Slovenia and Montenegro. Its comparative advantages should be tested in the Dubrovnik area, so that it may be further improved and more widely used.

A technique known from technical literature and extensively used in a number of countries consists of the following: by means of drilling bits, walls are drilled through the centre in parallel with the external plane and at various

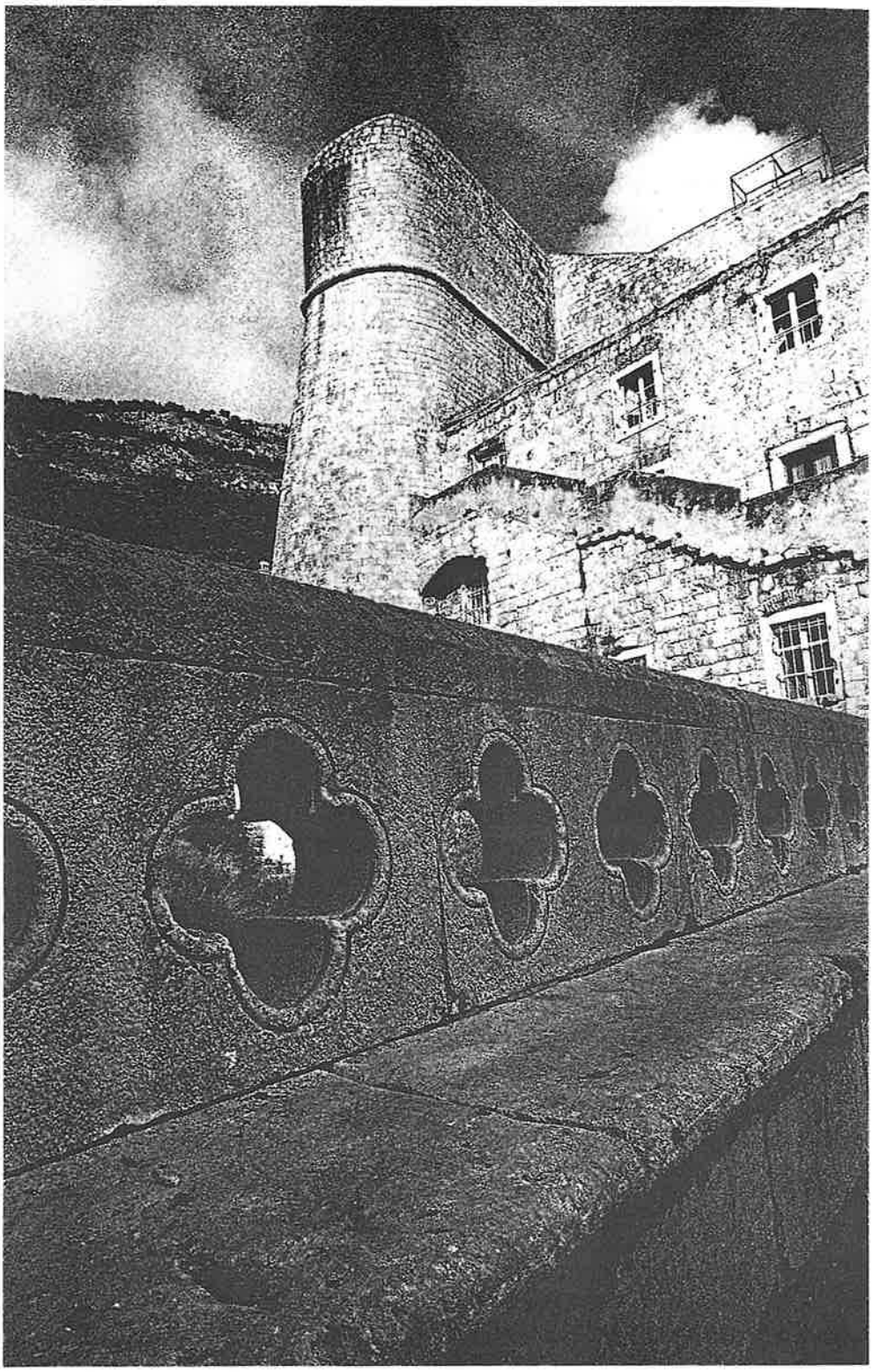

Fig. 9. (Knut Vibe Rheymer)

angles. Steel rods are then inserted into the internal grid obtained in this way and the reinforcement is completed by grouting. The advantage of this system of internal tie-beams is that it does not cause any external damage or loosening. The only visible traces of the operation are round holes several centimetres in diameter on the lateral surfaces of the opening. Moreover, it is ideally adapted to traditional characteristics of historic buildings and the specific requirements of their conservation. It effectively strengthens old structures, while reinforcing and grouting increases their seismic resistance; the strengthening is carried out in the core rather than on the surface of the walls, so that all the visible interior masonry is preserved; as distinct from aggressive repair techniques, the old walls are not damaged in any way. The technique is most easily applied in buildings with apertures separated by columns, and hence is resistant to seismic shock.

The method described above deserves to be studied, adopted and more widely used in this country. If it is subject to patent rights or any other constraints, this should not be

considered an obstacle in those cases in which it is the method of choice both in terms of strengthening and conservation. As in other problem areas in which the latest scientific and technological solutions are essential, UNESCO and its specialized agencies are a valuable help. The number and complexity of operations which the restoration of Dubrovnik's cultural monuments will involve, imposes the need for the widest possible range of solutions judiciously selected on the basis of practical experience.

Damp-proofing

All buildings in Dubrovnik are exposed to the effect of various forms of damp and many of them have suffered damage under its influence. This is especially true of the ground floors of buildings in the lowest lying parts of the city.

Damp acts in various ways, its most frequent occurrence being capillary action or seepage, in which damp penetrates from the subsoil into the ground level section of the walls and into pavements, which are not normally protected by horizontal insulation. The level which it reaches and which is more or less uniform depends on the saturation of the subsoil, the composition of the building material, evaporation rate, and similar factors. Damp in the ground level walls and floors makes the premises unhygienic and illsuited for use, particularly for permanent habitation. This can be remedied by horizontal, multi-layer proofing laid under the floors, i.e. by established damp-proofing techniques. Proofing the stone wall footings of old buildings against damp is a much more demanding task. A number of methods have been evolved by trial and error, each having some advantages and limitations, either technical or financial. The electroosmotic method uses the current between two electrodes (active and passive method); another method involves the forming of water-repellent zones by injecting solutions of suitable substances. A more radical method is based on drilling holes into thick walls and filling them with a mixture of hard and totally impervious aggregates and synthetic resins. An earlier method consisted in sawing through the walls and inserting overlapping lead sheets. All these methods are aimed at preventing the water column from rising. In cases where it is impossible to eliminate the cause of dampness in the walls, the aim of the proofing is to reduce its effect on the premises. This is done by erecting thin walls separated from the main wall by a narrow gap ventilated through openings at the top and bottom of the wall.

Another widespread form of damp in old buildings is caused by the condensation of water vapour in an enclosed space when it comes into contact with the colder wall, floor and roof surfaces. Unlike capillary damp, it is found at all levels in the building, for instance in the winter on top floors under flat terraces. It is especially common in buildings with massive structures, which get very cold in the winter and then gradually warm up in the spring. This leads to a phenomenon called thermal inertia. When warmer, moisture-saturated air penetrates into such buildings, condensation takes place. This happens even when the premises, particularly those in the basement, are continuously used.

Damp-proofing can be achieved by preventing the cooling of floors and walls through good insulation. Since this cannot be done by insulating the external walls in old buildings, internal linings or thin counter-walls can be used: the resulting interspaces act as thermal buffers. Thermal insulation of the floors is done by placing insulation materials between the layers of damp-proofing. Another method uses air chambers made of hollow bricks, placed under the top floor layer.

In complicated cases when it is important to preserve the original appearance of the interior and when no linings can be used, condensation may be prevented by using panel floor heating and by creating a stream of warm air along the bottom of massive walls. This has been used in other countries to insulate churches which are protected as historic monuments and are at the same time used from time to time for congregations at services or groups of visitors.

Dampness caused by multiple factors is not uncommon.

A concomitant of dampness and drying out of walls is the crystallization of salt solutions on wall surfaces, a direct consequence of which are salt deposits on stone surfaces (saltpetre) or the crumbling of the plaster lining.

The increasing emission of gases from boiler rooms, vehicles, ships, district-heating plants and industry, all of which use fossil fuels, has a highly destructive effect on old stone buildings. In contact with atmospheric humidity and precipitation, acid solutions are formed, many of which are sulphur based. The resulting chemical processes may lead to the transformation of solid lime-stone into a gypsumlike material subject to total disintegration.

The old city of Dubrovnik does not have a serious smog problem except in the parts of the town near the harbour, along the main transit roads and in the industrial zone.

Today a wide range of methods are currently used to combat damp and protect historic buildings from its destructive activity. Unlike the established and sometimes widely publicized commercial methods, scientific procedures are based on precise humidity measurements and the determination of the causes and mechanism of damp. Unless damp-proofing is preceded by a diagnosis obtained in this way, it may be a waste of money and even produce a higher degree of damp in the building.

These complex problems could be successfully tackled with the help of a research institution which would be entrusted with studying the buildings, designing the appropriate methods and supervising their application. International help can be obtained through UNESCO and well-known international research institutions specializing in damp-proofing techniques.

Façade conservation

The stone fronts of Dubrovnik's historic buildings bear witness to the supreme craftsmanship of old builders, stone-masons and sculptors. Built in the course of many centuries,

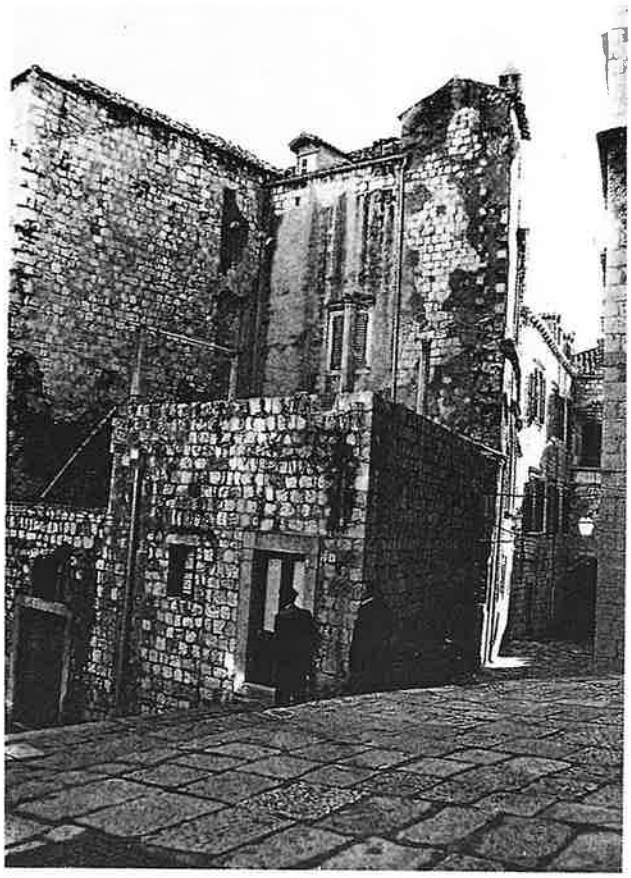

Fig. 10. (Tomislav Kralj)

they include uniquely beautiful specimens of Early Romanesque, High Romanesque, Floral Gothic, Renaissance and Baroque architecture.

Most historic buildings of Dubrovnik have retained their original façades. When reconstructions were undertaken, they were carried out in the interior of the buildings or in the ground level premises converted into commercial premises or workshops. The upper parts of Dubrovnik's façades, especially the main and public premises, embody a wide range of data on building and masonry techniques. In addition to the main and more obvious stylistic characteristics, they reveal many less conspicuous features of the period in which they were built. This is especially true of remnants of medieval architecture which have suffered major damage on a number of occasions, and of later rustic buildings.

It is to this multitude of minor, anonymous data, which is the only basis for reliable conclusions about period architecture, that special attention should be paid in conservation work, for it is the most liable to be lost in reconstruction and repair. It includes boundaries between the different stages in construction, segments of architectural openings or their outlines, re-used fragments of stone ornaments, etc.

Another source of information about building techniques is the fashioning of building blocks and types of mortar joints between stone blocks. Traces of stonemasons' tools on façades and the shapes of joints constitute important, sometimes the only information about the style and age of the building. It is therefore essential to prevent the loss of this kind of data in the course of reconstruction work. Many reconstruction plans include instructions to remove old joints and put in new ones. This is done even when there is no technical need to replace the old materials in the joints. Several valuable features are lost in the process: the authenticity of the original joints, the fusion of two related materials (stone and lime mortar), the unreproducible pattern of the old joints, which reveals the 'handwriting' of the builder and of various stylistic periods. The completely renewed joints of cement mortar commonly found today are the ready-made product of routine work and not only lack visual originality but are technically unsuitable.

Another pitfall that should be avoided is the removal of the surface layer by means of mechanical procedures, chemical solutions, sand blasting and other methods aimed at 'freshening' old discoloured façades. The result of this kind of restoration is irreversible — it destroys irrevocably valuable architectural characteristics and the data for the attribution of the building. Moreover, the removal of surface calcite and the crushing of stone crystals opens the way to the effect of water, frost, microorganisms, sea salt, etc. The only acceptable way of cleaning old buildings is washing the walls, using natural-fibre brushes.

In order to get durable, strong and authentic-looking joints it is necessary to use proper formulas and traditional experience. Today people all too readily resort to cement as an universally applicable ingredient in all stages of construction, from the foundations and structure to plastering and bonding. In addition to this industrial product, slaked lime is increasingly used as a building material not only for new structures but also for the repair of old buildings. Cement mortar is unsuitable for historic buildings especially for monuments because its hardness and brittleness make it incompatible with the physical properties of stone walls laid with lime mortar. Owing to the uneven thermodilatory activity of the different materials, joints begin to crack, thus becoming open to moisture and other detrimental influences. The stronger the mortar, the more pronounced are the negative effects. Slaked lime loses water rapidly, as a result of which the process of chemical binding is not completed and the mortar subsequently deteriorates rapidly. When on top of this, sea sand insufficiently washed free of salt is added as aggregate, the result is hygroscopic action (a permanent deficiency of façade plaster and bondings), the formation of blotches, surface erosion, etc.

What is more, such mixtures and building techniques are unacceptable in restoration work for aesthetic reasons. The dark grey tones of cement joints clash with the warm ochres and light greys of old stone walls. The mistaken and naive belief that joints prevent the penetration of atmospheric water into thick walls induces contractors to use flush mortar bonding, thus covering the joints between the stone blocks. This ruins the old ashlars, in which joints are so fine that only a very narrow face is exposed to atmospheric influence. After the application of this crude technique, even the most finely executed facing assumes a rustic appearance. The dark joints of mortar cement cannot be removed without severely damaging the ashlar, defacing its edges and smooth

Fig. 11. (Damir Fabijanic)

borders.

Successful restoration of historic façades can be carried out if traditional building techniques are combined with laboratory and site testing. This will involve the study of old, long forgotten or abandoned formulas, the use of traditional materials such as quicklime, aggregates of limestone purged of dust and other impurities, correct dosing, use and maintenance of humidity in mortar during initial binding, the shaping of joints according to patterns used by old masters, etc. All these are elements of a technological procedure adapted to the characteristics of historic buildings and the requirements of modern architectural conservation.

The scope of the work to be undertaken in Dubrovnik and the high level of expertise and professionalism it demands imposes the need for extensive research and preparations. Assistance from a number of research institutions from Yugoslavia and other countries should be obtained in order to find the most suitable techniques and materials. Routine solutions with their possibly undesirable consequences should be avoided by engaging an institution specializing in façade restoration and entrusting it with the preparation, materials testing and supervision of the project. The experience gained in the process could then be used in restoration work on similar buildings.

Roof restoration

The old city of Dubrovnik can be seen from various points and angles such as from the sea, the access roads, city walls and other locations. These panoramic views of the city present a 'fifth façade' — the numerous house roofs, between which the spectator can see the cloister gardens and the stone-paved squares and streets. Dubrovnik's roofs come in all shapes and sizes and are most often covered with pantile, generally of the old pre-industrial type with a whole range of colours. The soft,

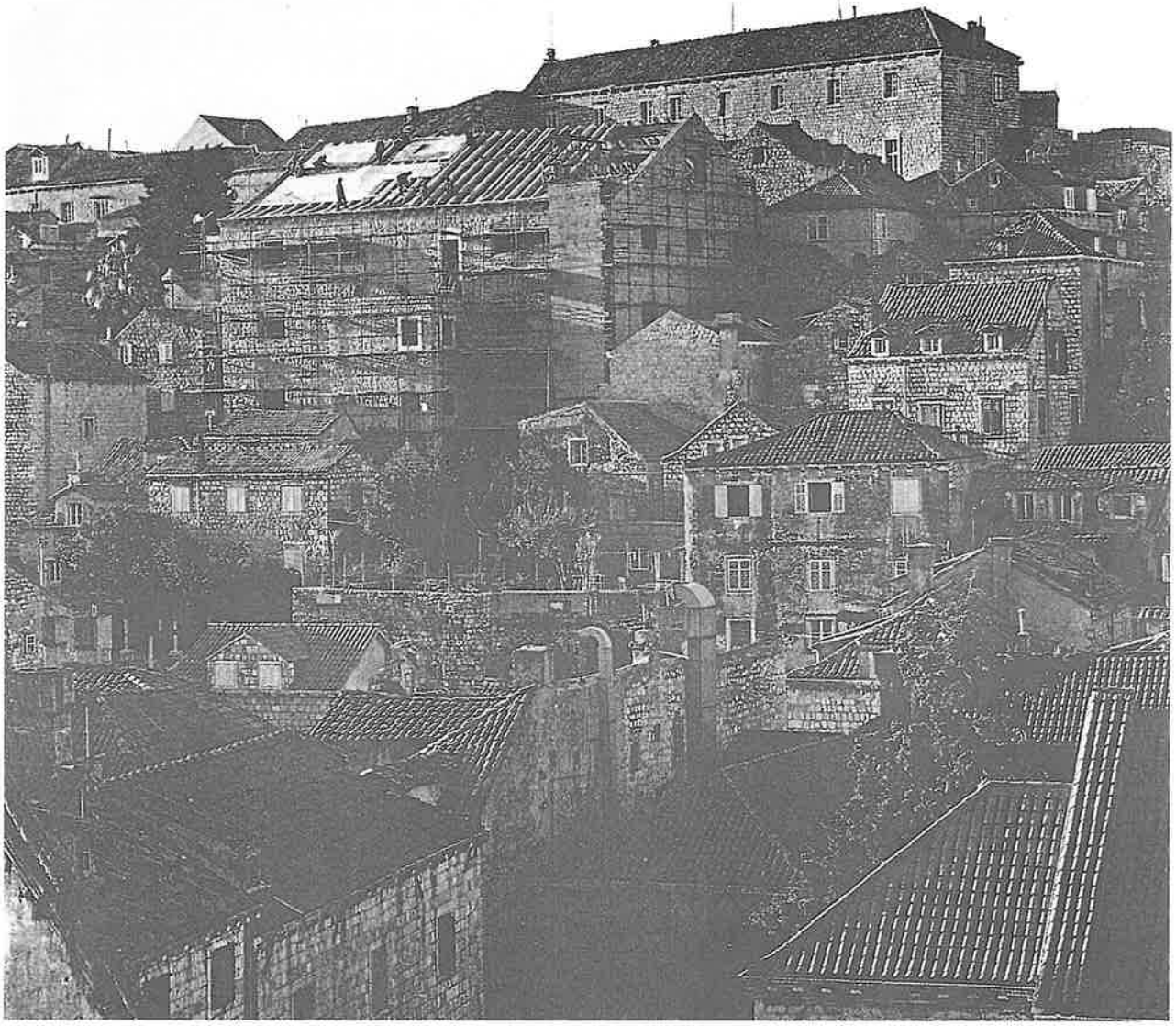

Fig. 12. (Damir Fabijanic)

irregular lines of the eaves and roofs are broken by attic windows and small loft openings. Many buildings have old chimneys with wide cowls shielding them from the wind. The subtle variety of tones ranging from light ochre to dark red with greenish-grey layers of algae on the pantiles produces a colour pattern that only a long passage of time can create.

This picture will change considerably when the repair work now under way is finished. The flexible and irregular lines of the roofs and eaves are now being replaced by sharper and more regular geometric shapes. Instead of the old tiles, new, mass-produced ones are being used, all of identical shape and colour. A number of old chimneys and small openings on the house tops will disappear. A concomitant of the improved repair of the buildings will be a uniform and dull appearance of their roofing. Although repair work on the roofs is indispensable, it should not claim as its victim the visual quality of the whole, the freshness of detail and the rich tones of burnt ochre found in the pantiles.

Instead of being written off by a one-sided decision, the old tiles could be carefully taken down and sorted to be used again either on the same roof or on other buildings. In the course of the next few years Dubrovnik will be a large building site, which warrants the employment of manufactures who would be willing to make roofing materials to order using old shapes and colour patterns. The cooperation between those responsible for the restoration project and tile manufacturers could considerably reduce the drastic changes in the shape and colour of Dubrovnik's roofs.

In view of the current narrow range of building materials and the total absence of any effort to manufacture materials for the restoration of old houses and towns, this need stands

little chance of being met.

However, the large scale of the project and the expected volume of orders may incentive for finding partners among building materials manufacturers.

If a supply of handmade pantiles is ensured, old tiles may be used for the upper courses and new tiles for the lower courses. This would satisfy both technical and aesthetic criteria, i.e. make the roofs impervious to rain and preserve their polytonality.

This undertaking must be carried out at a municipal level without regard to individual investors or contractors. Since the project is already under way, a comparison of the appearance of the roofs before and after repair confirms the need to protect and preserve the original design of Dubrovnik's roof tops, for it is an inescapable part of the overall picture of that unique city.

* This article was prepared in 1985 as a discussion paper for a meeting of the professional advisory committee for the renovation of Dubrovnik.

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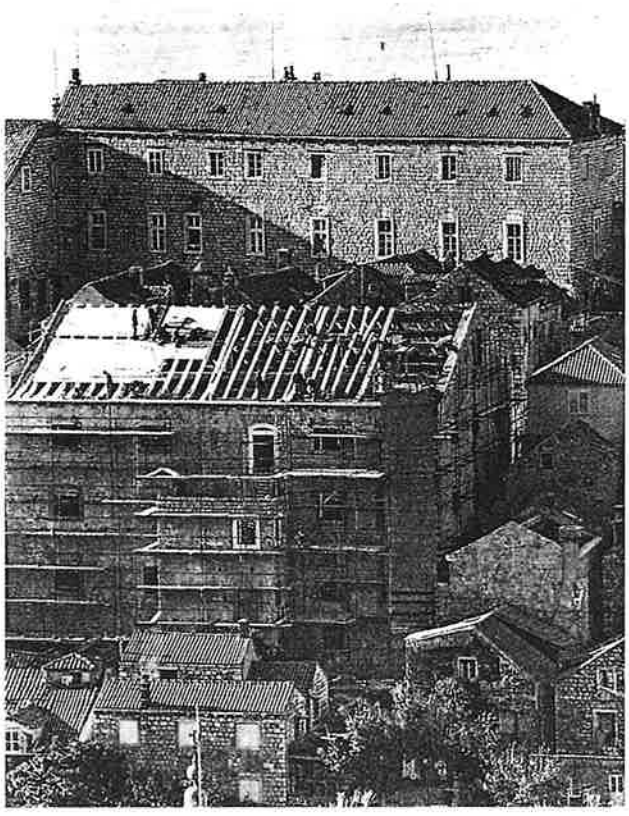

Fig. 13. (Damir Fabijanic)