Geotechnical, Geological and Earthquake Engineering

Matej Fischinger *Editor*

Performance-Based Seismic Engineering: Vision for an Earthquake Resilient Society

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Performance-Based Seismic Engineering: Vision for an Earthquake Resilient Society

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In honour of Peter Fajfar and Helmut Krawinkler, the founders of the Bled Workshops.

Preface

The desire for good performance is inherently built into the human mind, so that performance based design has always existed in one form or another. But the perception of performance has frequently been vague and insufficiently quantified. Even today the occurrence of major earthquakes continues to confirm that there are fundamental differences between the expectations of stakeholders and the performance which is actually provided by traditional design. Only about two decades ago increased public awareness and the simultaneous development of advanced engineering tools and methodologies matured enough to trigger activities leading towards the formulation of an up-to-date concept of performance based design.

Since the very beginning, Peter Fajfar and Helmut Krawinkler were in the forefront of these new ideas. They initiated and organized three famous workshops (those which were held in 1992, 1997, and 2004), which became known simply as the Bled Workshops – Bled is a small town in Slovenia, next to the nice Lake Bled, where the events were organized. These workshops produced widely cited reference books, which provided visions about the future development of earthquake engineering, as foreseen by leading researchers in the field. There are very few scientific events which can repeatedly bring together the best and leading researchers from all over the world, and thus provide a forum with a strong impact and authority for important developments in a particular scientific field. During Bled 1 (1992) the new emerging tools of nonlinear seismic analysis and design were discussed. These tools were, at the time, and still, are a prerequisite for modern performance-based earthquake engineering, a burgeoning idea that was incubated in the minds of the participants. During Bled 2 (1997) it became clear that performance-based design had become one of the leading new ideas in earthquake engineering. By the time that Bled 3 was convened, in 2004, the procedures and methods of performance-based design and evaluation, which had been developed during extensive research, were being gradually adopted into everyday practice.

Now, 20 years after the foundation of the tradition of the Bled workshops, we are witnesses to a world-wide breakthrough of this idea, with many different implementations and applications. The major research activities in the field of

performance-based earthquake engineering have been supported and coordinated by large networks of research institutions and laboratories. However, even if this significant progress is taken into account, the earthquake engineering community still faces many big challenges. Over just the last 5 years, several devastating earthquakes have reminded us that these destructive events still threaten the lives of millions of people, and very large amounts of property, as well as the social structure and economic well-being of individuals, communities, and countries all over the world. These events have clearly demonstrated that some of the traditional concepts of performance based design are becoming out-of-date. First of all it has become clear that our research interest should go beyond the narrow technical aspects, and that the seismic resilience of society as a whole should become an essential part of the planning and design process. The Bled 4 workshop was organized in order to discuss, develop and promote this idea in the light of the state-of-the-art achievements in the field, and this book presents the outcomes of this event. The workshop started exactly 20 years after the day when Slovenia had declared independence, 40 years after the Institute of Structural Engineering, Earthquake Engineering and Construction IT (IKPIR) had been established at the University of Ljubljana, and 500 years after the strongest earthquake to ever hit Slovenian lands, which occurred in 1511.

First of all, the participants of the 2011 event built on the tradition of the earlier Bled workshops, which were initiated by Professors Fajfar and Krawinkler, in order to honour their important research contributions. To our great sorrow, soon after the workshop the earthquake engineering community had to face the loss of Helmut Krawinkler, even while he was still actively contributing to the finalization of this book, which meant a lot to him. I will never forget Helmut's communication in January 2012, telling me "To put it bluntly, Bled 2011 was my last very good and lasting memory". Today this sentence fills me with both sadness and happiness. But first of all it committed me to fulfil Helmut's wish, and to get this book published, in spite of the problems which I had to face. In order to honour Helmut's memory, Gregory Deierlein prepared the introductory chapter of the book, based on Helmut's Power Point presentation, which was presented at the beginning of the 2011 workshop. So the book includes Helmut's last and priceless address to the engineering community, together with his vision and advice for the future development of performance based design and earthquake engineering. I am very grateful to Greg for undertaking this extremely difficult but most important task.

Our joint aim has been to develop a common global vision for earthquake engineering and seismic risk management, while at the same time recognizing the unique regional traditions which do exist. This book therefore consists of three major parts (IV–VI), presenting the vision of the three world regions which lead in earthquake engineering – Japan and Asia, Europe, and the Americas. Whereas the majority of the chapters in the Americas group were contributed by authors from the western US and Canada, Part VI also presents the views and visions which are held in the eastern US, Mexico and Chile. In order to make sure that New Zealand, as one of the leading schools in earthquake engineering, was not missed out, Nigel Priestley contributed two chapters to the book. By doing so, in spite of the serious condition

of his health, Nigel proved his great energy and devotion to research, and – I can dare say – also his friendship to me. I am therefore very grateful to him for ensuring that his views could be given in this book, thus providing a more complete picture of the vision of future code developments. And primarily, I express my gratitude to the regional coordinators Masayoshi Nakashima (Japan/Asia) and Peter Fajfar (Europe), as well as Jack Moehle and Andrei Reinhorn, who together coordinated the Americas group. The regional coordinators proposed invited participants and contributors, defined the regional concept of the presentation, and served as one of the two reviewers of each chapter required by the publisher. Without their unswerving support I would not have been able to finish this task. I am particularly obliged to the Japanese researchers, who participated in spite of the enormous commitments and day-and-night work which they had to perform in the months immediately following the 2011 Tohoku Earthquake. Here I would like to express my special thanks to Masayoshi Nakashima, who gave the final initiative for the Japan/Asia group to participate.

After Helmut's introduction (Part I) the book starts with Part II – Global Vision – which first includes three chapters contributed by three distinguished researchers from the three participating regions, giving a broad introduction to the problems to be discussed and considered. The first chapter was contributed by Stephen Mahin, the director of the Pacific Earthquake Engineering Research Centre (PEER). The PEER Centre has always been among the leading institutions which have been involved in the development and promotion of performance-based-design (PBD) methodologies. The "PEER methodology", which is used by many authors in this book, is frequently considered to be synonymous with PBD procedures in general. In this chapter, entitled "Engineering Challenges on the Way to Resilient Structures and Communities", the engineering aspects of resilient communities are discussed, focusing on the question of how to increase the post-earthquake operationality of those structures and on the lifelines which are critical to a community's needs in the aftermath of a major earthquake, and the ability of occupants to "shelter-in-place" during repairs. Hiroshi Akiyama, Professor Emeritus of the University of Tokyo, a close friend of both Peter Fajfar and Helmut Krawinkler, contributed the chapter on the use of energy principles in earthquake engineering. The importance of this contribution is best described in the review written by Masayoshi Nakashima: "A legendary design concept developed by Professor Akiyama is summarized in this chapter. The importance of cumulative structural damage is emphasized, and the concept of energetic equilibrium is the plausible answer to allow for the damage. The chapter should be published as a historical note to 'energy-based seismic design'." While this concept has not, recently, been sufficiently addressed, I am convinced that many performance objectives and goals on the path towards resilient structures will be more efficiently achieved using energy principles. The third chapter was written by Žiga Turk, who served both as Minister for Economic Development, and as Minister for Education, Research, Culture and Sport in the past governments of the Republic of Slovenia, as well as acting as Secretary General of the Reflection Group on the Future of Europe. Žiga Turk analyses the profound changes that the world is going through, and how civil engineering should respond

to these challenges. Concluding with the statement that "the essence of technology is nothing technical" he supports one of the main observations in this book, that PBD should go beyond narrow technical interests, and should focus on the resilience of communities and society. Three more papers in the Global Vision part of the book address important developments in the codification of direct displacement-based seismic design, and the earthquake resistant design/retrofit of bridges with advanced materials.

As mentioned above, several devastating earthquake disasters (Haiti, Chile, L'Aquila, Tohoku, and Christchurch) occurred shortly before the 2011 workshop. Most workshop participants were involved in the post-earthquake reconnaissance and disaster-relief efforts. This valuable experience has been incorporated into all chapters of the book, and in particular into Part III – New Vision after Recent Earthquakes. These disasters occurred in very different, and very differently developed, parts of the world. However, they all had consequences that were far beyond those expected, and they all revealed significant weaknesses in the expected performance evaluation and earthquake preparedness plans. The main message of this part is best described by Masayoshi Nakashima: "If 'resiliency' is defined as the ability to recover to normal conditions as quickly as possible, then true resiliency cannot be obtained by focusing on individual components separately. ... As long as building performance is investigated on only an individual basis, a full picture of the community performance cannot be obtained." There is also one very important message to be given. We too often concentrate on earthquake engineering procedures which are only suitable for developed countries. However, out of all the above-mentioned events, the Haiti earthquake was the worst, if not the worst earthquake catastrophe in modern history. As pointed out by Eduardo Miranda (Chap. 9): "Resilience encompasses on the one hand a measure of the impact of earthquake on society and on the other the capacity to recover from the disaster." Consistently with this, Sergio Alcocer (Chap. 32 in Part VI) has analysed the specifics of developing countries which determine the earthquake preparedness activities that are suitable for this environment.

At a time very soon after the Tohoku earthquake, we were honoured by the presence of His Excellency Toshimitsu Ishigure, the Ambassador of Japan in the Republic of Slovenia, at the opening session of the Bled 4 workshop. The Ambassador talked about his own broad personal experience of earthquakes, particularly when he was involved in several rescue activities as the Head of the Overseas Disaster Assistance Division at the Ministry of Foreign Affairs. He led the disaster relief team after the Earthquake of North Afghanistan in 2002, and after the Tsunami disaster in Phuket in 2004, and he was personally involved in the rescue operations after the 2003 Algeria earthquake. In Kobe 2005 he was involved in the establishment of the International Recovery Platform, which is the worldwide conference on disaster prevention under the auspices of the UN. As a guest of honour, he addressed the participants of the Bled 4 workshop with the following words: "First of all I would like to express my sincere gratitude to all Slovenians and citizens from other countries for their heartfelt sympathy and solidarity with Japan, which is now facing difficulties due to the huge earthquake and tsunami

disaster on March 11 this year. However, Japan will not simply rebuild, but rather reshape itself into a more dynamic country. Today, I am really grateful for being able to take part in the Bled 4 Workshop: Performance Based Seismic Engineering-Vision for an Earthquake Resilient Society. Especially, at this moment after the disastrous earthquakes which happened this year, I think we have a great opportunity to learn from these experiences in order to minimize casualties and to prevent secondary disasters, and the need for this kind of study is highly regarded among the people as well. ... Having seen with my own eyes the aftermath of earthquake disasters, I am really well aware of the importance of preventive measures for potential natural disasters, and the importance of developments in the technology of seismic engineering. I am therefore firmly convinced that, from your research and discussions which will be exchanged at this conference, new knowledge and technology to prevent disasters and minimize earthquake casualties will emerge, and so contribute to saving as many lives as possible in potential earthquake disasters all around the world. I wish great success to the Bled 4 workshop."

The second guest of honour at the Bled 4 workshop was Professor Matjaž Mikoš, the Dean of the Faculty of Civil and Geodetic Engineering of the University of Ljubljana, who, as a hydraulic engineer and as a hydrologist active in the fields of landslide mitigation and flood prevention, fully understands how important performance-based seismic engineering is in order to build an earthquake resilient society. In his welcome speech he said: "It is a special privilege to be in a position to work together with Professor Fajfar in the same faculty, and therefore I will take the opportunity of this opening address and express my personal and our faculty's sincere thanks for the contributions of Professors Krawinkler and Fajfar, who have contributed so much to the field of seismic engineering, and who are the founders of these scientific workshops at Bled. The International Decade for Natural Disaster Reduction, in the last century, intensified international cooperation and initiated new ways of thinking in this field ... . Different natural hazards such as tsunamis, earthquakes, volcanic eruptions or floods are inevitable on this Earth, but we can build up our capacities, prepare early warning plans, raise levels of preparedness, and work hard on prevention. And this is precisely what you will be working on during these days at Bled."

Significant speeches were also given by Peter Fajfar's former post-graduate students, who had achieved high-ranking positions in Slovenian society, and in the institutions which are responsible for natural disaster prevention. Roko Žarnić addressed the audience as the Minister of the Environment and Spatial Planning of the Republic of Slovenia. He presented the efforts for upgrading the disaster resilience of the Slovenian community by introducing the newly established Slovenian Council for Measures of Seismic Resilience, and described the recovery efforts after recent earthquakes in Slovenia. Črtomir Remec, the President of the Slovenian Chamber of Engineers and the President of the European Council of Engineering Chambers, emphasized the importance of PBD methodologies for the development of design practice.

Browsing through this book, which has emerged as the main result of the Bled 4 workshop, I hope that it will continue the tradition of the excellent "Bled

Fig. 1 Bled 4 workshop participants

publications", which have served as reference books in earthquake engineering. There are many people who have contributed to this success. Firstly, I would like to express my gratitude to Atilla Ansal, the Secretary General of the European Association of Earthquake Engineering and Springer's Geotechnical, Geological and Earthquake Engineering Series Editor, for his kind and encouraging consideration of this book, and Petra Steenbergen, Springer's Senior Publishing Editor, for her help and patience with the delay in the preparation of the manuscript. And I am, of course, deeply grateful to the invited authors (the first authors of all the chapters, as well as Patricio Bonelli, Gian Paolo Cimellaro, Gregory Deierlein and Gaetano Manfredi) and their co-authors (please see the List of contributors), who put a lot of effort and care into preparing the 32 chapters of this book in spite of their very busy schedules. I equally thank the other invited participants – Boštjan Brank, Mehmed Čaušević, Vojko Kilar, Vladimir Sigmund and Roko Žarnić – who participated in the interesting and fruitful discussions. I am particularly obliged to Božidar Stojadinović, with whom we planned this wonderful event for several years. I conclude this introduction with a group photo of the Bled 4 workshop participants, as a lasting memory of this event (Fig. 1).

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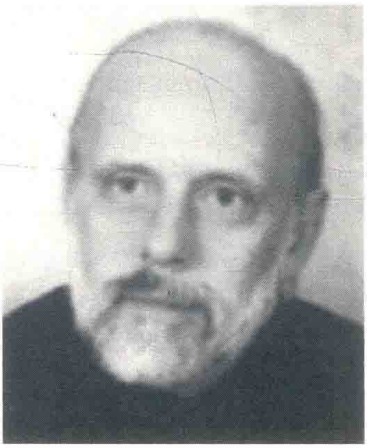
Matej Fischinger

About the Editor



Matej Fischinger (born in 1954) is a Professor of Earthquake Engineering and Reinforced Concrete Structures at the University of Ljubljana in Slovenia. He is a Member of the Slovenian Academic Society of Technical and Natural Sciences and the Vice-president of the Slovenian Association for Earthquake Engineering.

His research has been concerned with earthquake resistant design of RC structures and the inelastic design procedures. He is the co-author of the N2 method, proposed in 1989 in his Ph.D. dissertation supervised by Professor Fajfar. For the related research work they got the highest research award in the Republic of Slovenia. Since then the N2 method, which was recently incorporated into Eurocode 8, has become one of the leading push-over methods in earthquake engineering. His current interest is in the seismic resistance of bridges, RC industrial buildings and structural walls, performance-based design methodologies, the Eurocode, and the use of information technology in education. Using inelastic macro-models the research group led by Matej Fischinger made several successful benchmark predictions of the response of RC structural walls.

As a designer, consultant or reviewer, he has participated in many design projects (in particular of high-rise apartment buildings, bridges, industrial buildings, precast buildings, NPP Krško and related buildings). He has been very active in the development of the EC8 and its introduction as a National code in Slovenia. Slovenia was the first country to adopt Eurocodes as the national code on January 1, 2008. He wrote the commentary for the RC section. He has actively participated in the recent modifications of the design rules for prefabricated structures in EC8. These results are based on extensive research within several EU research projects, where Matej Fischinger served as the Slovenian co-ordinator.

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