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Reflections on the Presentation of Fatigue in Design Codes

Considérations sur la prise en compte de la fatigue dans les règlements

Überlegungen bezüglich der Behandlung von Ermüdungsproblemen in Vorschriften

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SUMMARY
Some thoughts are presented on the transformation of scientific research findings into a form suitable and acceptable for use in practice. With regards, in particular, to fatigue the paper discusses both the load processes involved and the general structural requirements to be fulfilled. The ways and means of meeting these requirements are mentioned for planning, design, execution and inspection in order to outline the considerations to be made in preparing practical guidelines.

RESUME
L'article présente quelques considérations relatives à la transformation nécessaire des connaissances scientifiques en règles pour l'application pratique. Il rappelle d'abord les différents types de charges répétées, puis il discute les performances exigées pour les structures; il analyse les mesures à prendre lors de l'étude et de la réalisation d'un ouvrage pour assurer qu'il fournira les performances exigées. Les informations indispensables qui doivent figurer dans les textes réglementaires sont ainsi mis en évidence.

ZUSAMMENFASSUNG
Es werden einige Überlegungen mitgeteilt, die die notwendige Umsetzung wissenschaftlicher Erkenntnisse in praktische Anwendungsregeln zum Gegenstand haben. Durch Betrachten der Einwirkungskollektive, der Bauwerksanforderungen und der Massnahmen, die bei Entwurf, Bemessung, Ausführung und Kontrolle zu einer zufriedenstellenden Realisierung des Bauwerks zur Verfügung stehen, werden die Informationen herausgestellt, die zu einer Ausarbeitung praktischer Regeln unumgänglich sind.

To contribute on an international level to the development and evolution in structural engineering and to provide the necessary prerequisites for technological and economical progress in planning, design and execution of engineering structures belongs to the mission of all associations assembled at this Colloquium. CEB's particular interest in this mission has always been directed toward the two following objectives:

1) To elaborate on a structural engineering level a synthesis of existing theoretical knowledge and practical experience.

2) To derive from this synthesis practical guidance for planning, design, execution and maintenance of concrete structures.

Working toward these aims means that CEB clearly defines its position as link between scientific research and practical application.

One particular field in which we consider this link to be of special importance is the problem area to which this colloquium is partly devoted: Fatigue of concrete structures. Observing the development in this field one can realize a growing gap between scientific findings and practical guidance.

Due to many characteristics distinguishing the load bearing behaviour of concrete structures their sensitivity to fatigue has been in general of less decisive importance in design considerations. A fact which explains the minor priority which had been given to fatigue problems in many national and international codes and recommendations [see also (1)]. However actual practice and future developments are showing that this will not necessarily be so in future. The choice of structural concrete for a wider range of applications (sleepers in railroads, road and air-field pavements, wind-power plants and off-shore structures etc) and the design of more slender members, particularly in modern transport facilities (resulting among other things from a higher exploitation of the structural resistance at the ultimate limit state) may lead to time dependent stress variations resulting in local stress histories which in fact can affect the fatigue resistance. It is therefore important to provide univocal guidance which allows the structural engineer to identify those cases where fatigue can be decisive and which offers to him adequate information for their correct treatment.

An indispensable step toward the preparation of practical guidance is the elaboration of a synthesis of knowledge from the designer's point of view. This requires the consideration of the state of the art in all subject matters involved: Action models, material science, experimental techniques, performance and design criteria, production technologies, execution experiences etc. It is this state of the art to which we expect the colloquium will contribute.

On which particular problem areas do we have a hope to gather information? I will try to identify these by presenting some conceptional considerations which may be appropriate when preparing practical guidance for the treatment of fatigue problems in concrete structures.

Semantic clarity - one of the fundamental prerequisites for rationally derived regulatory documents - leads us to a first important question requiring a clear definition of "Fatigue".

The expression fatigue is related to a change in material performance under repeated loads - expressed e.g. in time dependent properties -. It is therefore desirable to define reasonable classifications which relate particular alterations in the material properties to relevant types of dynamic loads. Since dynamic loads by definition comprise all arbitrary variations of actions in time, including e.g. repeated actions exerted on foundations by machines, on bridges by traffic and on off-shore facilities by waves, ground motions caused by earthquakes or shocks induced by impact and explosions, a classification - allowing a clear definition of what is meant by fatigue - may reasonably be based on the nature how the performance of structural members is changed under the different kinds of dynamic actions.

One possible interpretation limits the meaning of fatigue to the reduction in resistance due to a sufficiently large number of load oscillations between critical lower and upper limits. It should be noted that this interpretation relates the actions leading to fatigue to the transient situations (as they result under normal use) rather than to accidental situations [see (2)]. In this way it also allows to distinguish fatigue from phenomena resulting from accidental actions as explosions, impact or high intensity ground motions. Some clarification in the univocal definition of fatigue is expected from this colloquium.

A very large problem area is related to the modelling of representative load processes as they result from the various dynamic loads acting e.g. on rails for cranes, bridges, off-shore facilities etc. It is hoped that this colloquium will particularly contribute to this field of necessary information.

A further consideration with regard to the preparation of practical guidance leads us to the requirements a concrete structure is expected to fulfill.

Limiting the scope to the structural behaviour under normal use, the requirements shown on the following page have been defined [see also (3)]. Please note that "fatigue" is related to the local resistance in a section or an element of the structure as it results from the actual e.g. time dependent mechanical and geometrical properties.

The formulation of semantically correct regulations calls for the translation of these requirements in performance criteria which are technical expressions - containing quantitative limits - of the required performance.

Which of the required performances are directly affected by frequent load repetitions causing fatigue in concrete structures? In general safety as well as serviceability and durability. Safety through the possible reduction of the resistances of the constitutive materials concrete and steel, furthermore through the loss of bond e.g. at anchorages and splices but also through the possible decrease of ductility caused by the increasing tendency to brittle rupture of reinforcing and prestressing steel. Serviceability may, among other things, be affected by the increase of deformations, in particular due to the loss of bond and to the increase in concrete strains etc. Finally, durability can be affected by a possible acceleration in crack development and propagation which then may initiate physical or chemical deterioration processes (e.g. corrosion of reinforcement).

Having outlined the effects exerted on the structure we come to a third consideration concerning possible measures to be taken in order to assure the required structural performance. These will comprise measures related to the design and the dimensioning of the structural members, but also to their structural detailing, to the execution procedures and finally to the possibilities of adequate observation and maintenance under service. Regulatory documents will have to provide the appropriate design criteria guiding the different steps. In order to assure well performing structures much importance must be given to the necessity to treat all criteria as a whole [performance,design (dimensioning, detailing), execution, control and maintenance] in a way which reflects their contribution to the realization of concrete structures sufficiently reliable against fatigue. For example stress concentration may often be avoided or at least reduced when all influencing factors from planning and design via detailing and execution are appropriately studied.

PERFORMANCE REQUIREMENTS (Normal Use)		
SAFETY	STABILITY	RIGID BODY EQUILIBRIUM
		SYSTEM STABILITY
		MEMBER STABILITY
	RESISTANCE	STRENGTH
		FATIGUE
	DUCTILITY	STRAIN-, ROTATION CAPACITY
SERVICEABILITY	Limitation of DEFORMATIONS	
	Limitation of VIBRATIONS	
	TIGHTNESS (Liquids, Gas)	
	THERMAL INSULATION CAPACITY	
	ACOUSTICAL INSULATION CAPACITY	
DURABILITY	Limitation of STRUCTURAL DETERIORATIONS	

Completeness, uniqueness and correctness of the criteria formulated in regulatory documents require a clear understanding on how the structural performance will be affected by frequent load repetitions. It is expected that advanced information on that subject matter will be presented at this colloquium.

The formulation of criteria treating fatigue problems in design, detailing, execution, control and maintenance of concrete structures demands a competent understanding of the structural behaviour which must be based on scientifically sound theoretical models and proved by extensive practical experience. It is essential to dispose of sufficient information allowing a consistent modelling of the material behaviour as a basis for a mechanically and statistically clear definition of the parameters involved (concrete, reinforcement and their bond interactions). Furthermore behaviour models concerning structural elements (beams, slabs, joints, anchorage devices etc) need to be available and their interaction within the overall structure should be well understood.

Finally the a-priori verification of adequate resistance against fatigue requires a consistent reliability concept. The variation in time of the actions and the resulting effects on safety, serviceability and durability of structures will favour concepts based on design service life considerations. Although intellectually appealing, such a concept requires profound considerations concerning its technical and legal implications.

This very general tour d'horizon from the standpoint of CEB raises many questions. Certainly more than we are able to answer at this colloquium. Scientific research will have to go on and practical experience will have to be made. However we hope that this colloquium will evidence sufficient knowledge which allows CEB to improve practical guidance for the treatment of fatigue problems. This improvement should include the separation of those cases where fatigue phenomena need not to be considered from those where safety, serviceability and durability may be affected by repeated loadings. In order to treat the problem with appropriate simplicity, it should be possible to subdivide the second class in cases where a simplified treatment may be sufficient and in cases where more refined load histories and corresponding fatigue processes considering damage accumulations should be taken into account in order to assure the required structural performance at economical conditions.

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[2] JOINT COMMITTEE ON STRUCTURAL SAFETY (JCSS): "General principles on quality assurance for structures" and "General principles on reliability for structural design", IABSE-Report, Vol. 35 (1981)

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