COMPUTER CONTROLLED TESTING
AUTOMATISIERTE VERSUCHSAUSFÜHRUNG
ESSAIS COMMANDES PAR ORDINATEURS

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SUMMARY

The computer control of experiments provides an efficient solution in case of complex load histories and large number of measurements. The appropriate load histories can be chosen without limiting the number of measurements, the duration or the schedule of tests. The supervision of tests and the data registration are continuous and safe. The registered data can be then directly evaluated with computer. Computer controlled pull-out tests with specific load histories are demonstrated.

ZUSAMMENFASSUNG

Die Computersteuerung von Versuchen eröffnet eine sehr effiziente Versuchsausführung bei umfangreichen Messungen oder bei speziellen Beanspruchungsgeschichten. Beliebige Beanspruchungsgeschichten können ohne Zeitbeschränkung für den Versuch selbst oder für die Messungen aufgebaut werden. Während des Versuches erfolgt eine ständige Überwachung und eine sichere Meßdatenerfassung. Die Meßdaten können dann direkt mit Datenverarbeitungsprogrammen weiter verarbeitet werden. Erste Erfahrungen mit Computersteuerung werden an Ausziehversuchen mit spezifischen Beanspruchungsgeschichten dargestellt.

RÉSUMÉ

Par la commande par ordinateurs d'essais il devient possible de réaliser des essais très efficaces à la base d'un grand nombre de mesures ou d'histoires d'efforts spéciales. Des histoires d'efforts quelconques peuvent être établies sans restriction du nombre des mesures, de la durée ou du déroulement de l'essai même. Les essais sont continuellement surviellés et les dates de mesure enregistrées. Les dates de mesure peuvent être évaluées directement par l'ordinateur. Les premieres expèriences sont démontrées sur des essais d'arrachement sous efforts spécifiques.

Keywords:

computer control, data acquisition, test supervision, load history, cyclic loads

1. INTRODUCTION

The computer control of experiments have essential **advantages** using complex load histories and large number of measurements or measuring points. The advantages are the regular and safe registration of measurements, in additon to the exact production of the required load history. The evaluation and representation of measurements can then be directly carried out on the registered data.

In case of a computer controlled test execution, the computer will provide all functions of test supervision and data registration. To be able to reach this purpose, a **digitalized hydropulsator and a personal computer are required** as hardware together with the necessary software in Quickbasic. A possible configuration of test setup is presented in *Fig.1*.

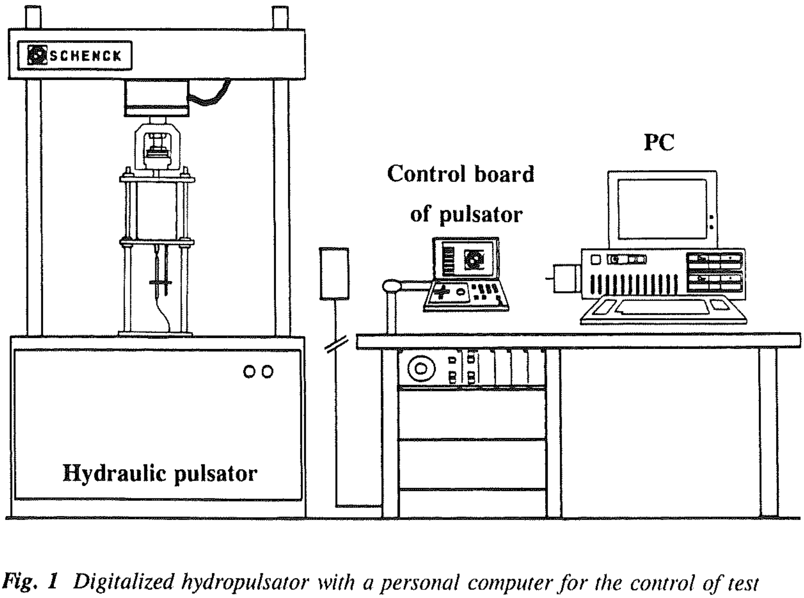

Fig. 1 *Digitalized hydropulsator with a personal computer for the control of test (Fig. 1 is based on figures of Ref. 1 extended with our actual test specimen)*

With the computer control **test run automatically** without interruptions for loading intervals or measurements of strains or displacements following the input of the basic parameters for the load and the data registration. The tests normally stop at a given limit of force, deformation, time or number of load cycles.

2. FIELDS OF COMPUTER CONTROL BY EXPERIMENTS

The three main fields of computer control in case of experiments are:

- *the load history,*
- *the data acquisition and the data registration* and
- *the supervision of tests*

2.1 Load history

Complex load histories can be constructed using the two basic types of loading which are **ramp** (loading with a constant rate) and **cycling** with a constant amplitude (*Fig.2*).

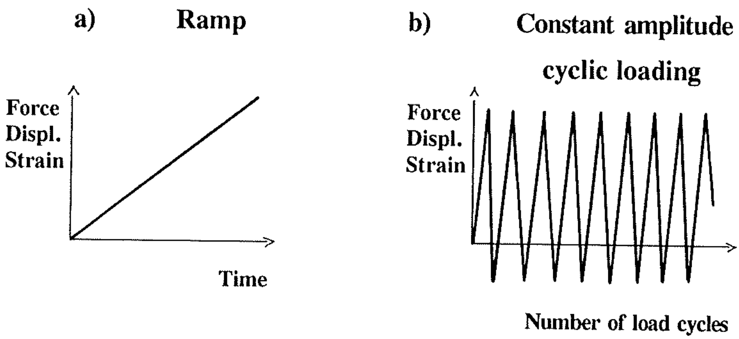

*Fig. 2 Basic types of loading: Ramp (**a**) and constant amplitude cyclic loading(**b**) – indicated here as a reversed cyclic loading*

In case of a **ramp**, the rate of loading and achieving the required force or displacement are basic parameters. In case of a **constant amplitude cyclic loading**, the mean load (force or displacement), the amplitude (force or displacement), the required number of load cycles and the characteristic wave form of cycles (sine, triangular or block) are to be defined, respectively.

The control of loading can be provided by the control of force or displacement of the cylinder, otherwise, by a measured strain or a displacement ,i.e. **force or deformation controlled tests**, respectively. (*Load* indicates either force or deformation and *deformation* indicates displacement or strain in the following.)

From the two basic types of loading — ramp and constant amplitude cyclic loading - any specific loading can be constructed within any region of the capacity of the hydraulic machine. These include loadings with or without sign change (tension-compression) of the controlled force or displacement acting on the specimen, which are often adressed as **cyclic and reversed cyclic loadings**, respectively. A continuosly varying cylic load history can be stepwise approached where the length of a step with constant amplitude loading should be based on practical decisions concerning the cycles that are necessary to reach the required amplitudes which is a function of the load level and frequency. In the range of 0.5 to 5 s^{-1} frequency and an amplitude of 1 to 40 kN, it needs 1 to 20 cycles.

Whenever one block of loading does not induce a failure of the specimen, the load history can be repeated.

Based on the analysis of the **practical load spectra**, various cyclic load histories were developed with varying amplitude or mean value. In addition to *random variation of the cyclic load* these include parabolic, *linear and logarithmic variations with increasing or decreasing tendencies* (***Fig. 3***). To produce a required maximum cyclic load, the minimum cyclic load or the amplitude can be kept constant.

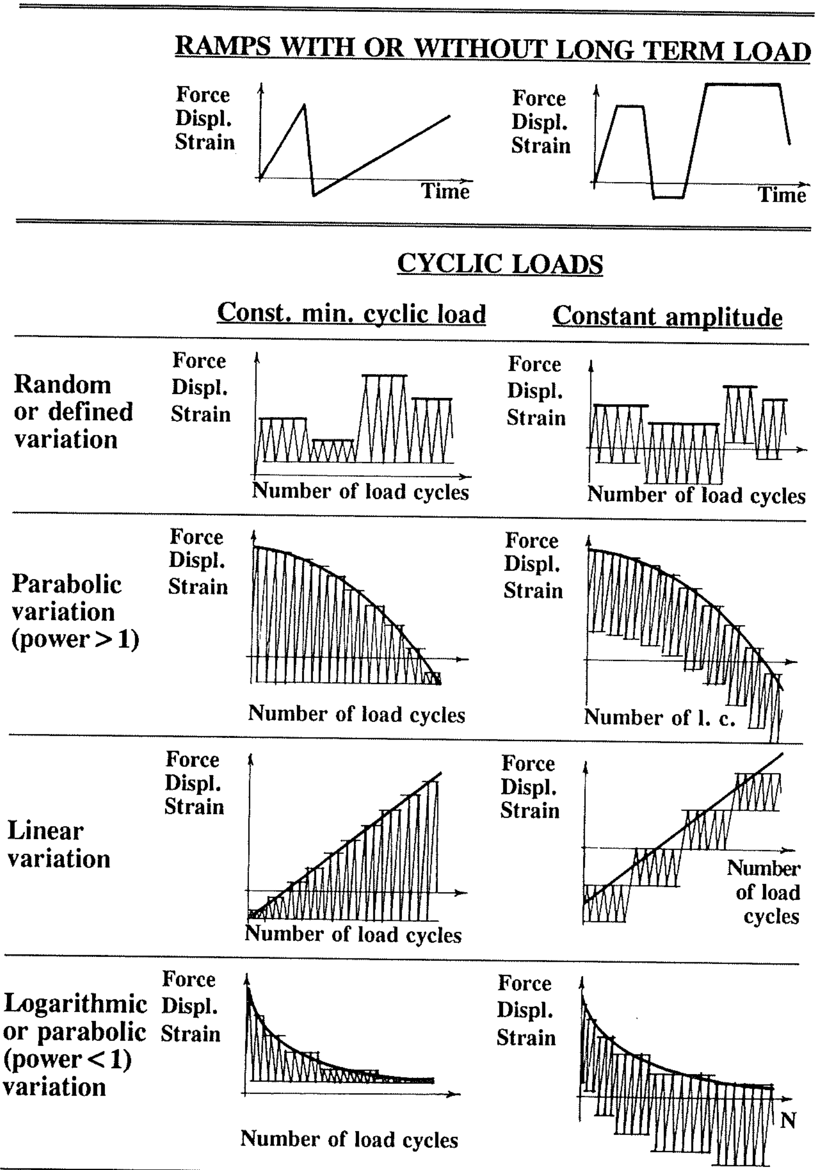

Fig. 3 Load histories (and their combination) applicable in computer controlled testing

All of the above load histories can be force or deformation controlled providing practically **all necessary cases of loading** required for testing.

2.2 Data acquisition and registration

There are two possibilities to carry out measurements and their registration during a test. The conventional way based on a manual test control to stop the test and make **readings at the mean cyclic load**. The computer control, however, opens the possibility of making **readings during the running test if a given extreme value of force or deformation (maximum or minimum) is reached**. Its obvious advantages are the uninterrupted test in addition to the control of readings according to deformation or force limits governed by the physical behaviour of the material or the structural element.

The measurements may be **registered and evaluated by the computer** following the readings. To avoid loss of data during an electric power failure, a sequential data registration is suggested.

2.3 Supervision of the test

In addition to reach the required data on the behaviour of the specimen, it is necessary to **avoid any damage of the experimental setup or machinery**. Both for regular and for unforseen failures of the specimen, large deformations and fast changes of the applied force are induced. Reaching a given force or deformation limit, the specimen is to be **unloaded**. Limit values are provided by the hydropulsator as its capacity limits that may be restricted through computer control based on reasonable actual limits. Unloading can be carried out to the initial load, to a required load or switching off the hydropulsator at once if necessary.

3. EXPERIENCES WITH COMPUTER CONTROLLED TESTING

Computer controlled pull-out tests with specific cyclic load histories in addition to some specific software details are discussed herein. The study is a part of an extensive experimental project on the behaviour of reinforced concrete structures under service load conditions.

3.1 Pull-out tests with computer control

Within a study on the cyclic bond behaviour of reinforcement, cyclic load histories were applied with linearly, parabolically, logarithmically and randomly varying amplitudes on different load levels and block lengths, in addition to the constant amplitude cycling. (The specimen and the test setup are indicated in ***Fig.1.***) The minimum value of the cyclic load was always taken as 10 % of the maximum repeated load.

The **parabolic** variation was given as:

$$\tau_{max}=\tau_{MAX}[1-(1-\tau_{min}/\tau_{MAX})(N/N_b)^2]$$

and the **logarithmic** variation as:

$$\tau_{max}=\tau_{MAX}[\tau_{min}/\tau_{MAX}+(1-\tau_{min}/\tau_{MAX})\sqrt{1-\log N/\log N_b}]$$

where τ_{min} and τ_{max} mean the minimum and maximum values of cyclic load, and τ_{MAX} is the highest maximum cyclic load in a given block of loading. The length of one block (N_b) has been chosen to 10^4, 10^5 or 10^6 load cycles, giving 2, 20 or 200 blocks up to 2 million load cycles, respectively. The linearly and nonlinearly variable cyclic load histories were set up in stepwise fashion using 10 sub-blocks of constant amplitude loading.

Grade and diameter of steel bars, mix proportions and curing of concrete, wave form and frequency of cyclic load were kept constant.

The maximum cyclic load levels of blocks (τ_{MAX}) were taken as 60, 50 and 40 % of the monotonic pull-out strength (τ_{bu}, which was 16 N/mm^2 as an average value). The specimens were subjected to a sinusoidal cyclic load with a frequency of 4 s^{-1}. In addition to the applied load, the slip of the unloaded section was measured with an LVDT and registered at specific values of slip and number of load cycles without interruption.

Figs.4 and 5 indicate the development of measured slip in case of 20 blocks of stepwise linearly decreasing cyclic load and in case of 200 blocks generated in a random manner. The ratio of the highest maximum cyclic load in a block to the pull-out strength (τ_{MAX}/τ_{bu}) was 60%. The test run automatically 6 days providing the required load and the data acquisition.

Further details of the above test results are given in Refs. 3 and 4.

3.2 Some specific software details

To serve the hydropulsator with parameters otherwise for the acquisition of data, Quickbasic subroutines are available ([1] and [2]). These include for example the definition of the type of load, reading of the actual number of load cycles or reading of the mean or the extreme values of force or deformations, etc.

Starting the program of computer control, first the communication between the PC and the hydraulic machine is to be initiated which is followed by the load parameters and their limit values. Following a measurement in the starting position, any combination of the above load histories can be produced. At the end of the test the specimen is to be unloaded and finally the communication between the PC and the hydraulic machine

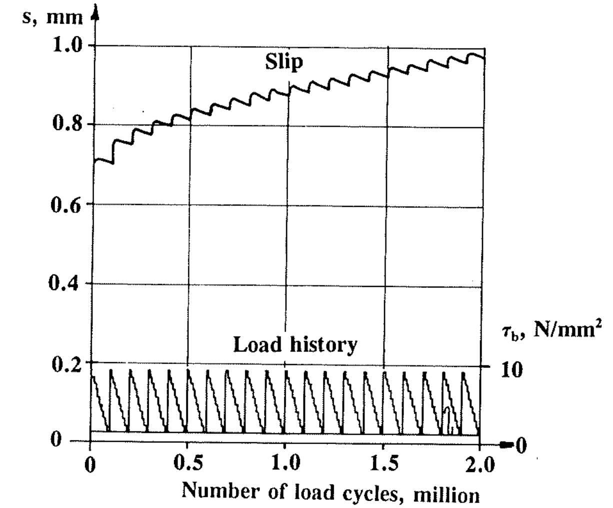

Fig.4 Slip increase as a function of load cycles in 20 blocks of cyclic load with linearly decreasing amplitudes; Ø16, f_y=500 N/mm², f_c'=25 N/mm², ℓ_b=5Ø, τ_{MAX}/τ_{bu}=0.6

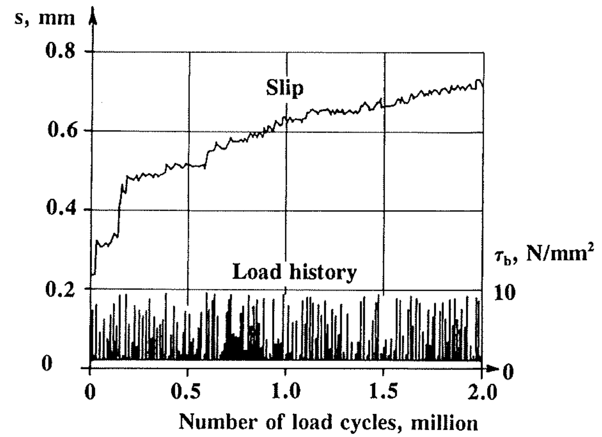

Fig.5 Slip increase as a function of number of load cycles in 200 blocks generated in a random manner; Ø16, f_y=500 N/mm², f_c'=25 N/mm², ℓ_b=5Ø, τ_{MAX}/τ_{bu}=0.6 (One coloumn of loading indicates 10 000 load cycles with constant amplitude.)

is to be interrupted.

4. CONCLUSIONS

In additon to the advantages of computer control of experiments, the provided possibilities for loading and measurements are discussed.

In case of **numerous measurements and complex load histories**, the computer control gives a convenient supervision of the test and regular measurements. Any kind of load histories can be developed **without limitations** in the number of measurements, duration or schedule of the test.

The computer control makes possible that **a test runs totally automatically** without interruptions for loading intervals or measurements. The supervision of test is continuous and the data registration is safe during the test. The registered data can be directly evaluated with computer.

Results provided by computer control are demonstrated on **pull-out tests with specific load histories.**

5. ACKNOWLEDGEMENTS

The financial support of the German Research Association (Deutsche Forschungsgemeinschaft) on the study of the cyclic bond behaviour is gratefully acknowledged. The computer controled system of testing was developed to produce the required rather special load histories and enable regular measurements for tests running several days under cyclic loading.

6. NOTATIONS

N	number of load cycles	-
N_b	number of load cycles to the end of a block	-
τ_b	bond stress	N/mm²
τ_{bu}	bond strength obtained by monotonic loading	N/mm²
τ_{MAX}	highest maximum cyclic load in a block of loading	N/mm²
τ_{max}	maximum value of cyclic load	N/mm²
τ_{min}	minimum value of cyclic load	N/mm²

7. REFERENCES

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