実験報告書様式（一般利用課題・成果公開利用）

（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。 ）

MLF Experimental Report	提出日 Date of Report , 2013
課題番号 Project No. 2012B0058 実験課題名 Title of experiment Fundamental study on strain measurement of rebar in reinforced concrete using pulsed neutron diffraction 実験責任者名 Name of principal investigator Koichi Kusunoki 所属 Affiliation Yokohama National University	装置責任者 Name of responsible person Kazuya Aizawa, Stefanus Harjo 装置名 Name of Instrument/（BL No.） TAKUMI/ BL19 実施日 Date of Experiment Mar 8th – Mar 10th, 2013

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Air-cured cylindrical reinforced concrete with 50 mm diameter and 460 mm length was provided to the experiment. The rebar embedded in the concrete was the ferritic steel bar with 10mm diameter.

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）

Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

The reinforced concrete is well known as a composite material consisting of rebar and concrete, thus the measurement of the strain distribution along the rebar embedded in the concrete are important to understand the bonding condition between the rebar and the concrete. In previous studies using angular dispersive neutron diffraction [**Suzuki et al., Powder Diffraction, 24 (2009) S68-S71**], it was confirmed that the oven-dried concrete makes it possible to measure strains in the rebar inside the concrete using neutron diffraction since neutron attenuation by hydrogen can be reduced by drying water in the concrete. However, it has been concerned that the material strength of the oven-dried concrete may be different from that of a typical air-cured concrete. In this study, therefore, the strain measurement of the rebar embedded in the air-cured concrete was performed by time-of-flight neutron diffraction using the TAKUMI engineering diffractometer.

The strain distribution was measured along the rebar over a length of 300 mm including the un-bonding region of first 50 mm length under different pull-out loadings, e.g., approximately 33 MPa, 125 MPa and 250 MPa. The nominal gauge volume was 5×5×10 mm^3 defined by the radial collimators and the gauge definition slit. The macroscopic strain was obtained by fitting 15 peaks from 111 to 431 reflections by the Rietveld refinement method using Z-Rietveld. The axial and radial strain distributions along the rebar were measured for each loading step.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

Figure 1 shows the axial and radial strain distributions along the rebar measured using neutron diffraction. The strain-free lattice constant at an unloaded condition was predicted by extrapolating the change in the lattice constant in the un-bonding region as a function of the applied stress. Typical compressive residual strains in the axial direction were observed in the bonding region due to drying shrinkage of the concrete. On the other hand, cross-sectional shrinkage of the rebar was observed in the anchorage zone. Figure 2 shows the axial and radial stress distributions along the rebar calculated by Hooke’s law under the equiaxial-stress condition using Young’s modulus and Poisson’s ratio derived from the change in the lattice constant as a function of the applied stress in the un-bonding region. Compressive residual stresses, about 56 MPa, were generated in the axial direction due to drying shrinkage of the concrete. Furthermore, compressive residual stresses, about 26 MPa, was appeared in the radial direction due to the same reason as well. Typical increase of the tensile stress in the axial direction was observed in the anchorage zone. The slope of that seemed to be constant regardless of the applied stress, meaning the average bond unit stress was constant. The lengths of the anchorage zone were estimated to be about 75 mm for 125 MPa and about 110 mm for 250 MPa. On the other hand, the radial stress distribution was not changed even when increasing the applied stress, which indicates that the radial deformation of the rebar was not restricted by the surrounded concrete.

As described above, the stress distribution along the rebar in the air-cured concrete was successfully measured accurately using time-of-flight neutron diffraction. New knowledge on the detailed deformation state of the rebar including its cross-sectional shrinkage will bring breakthrough ideas to optimization of the concrete structural design.

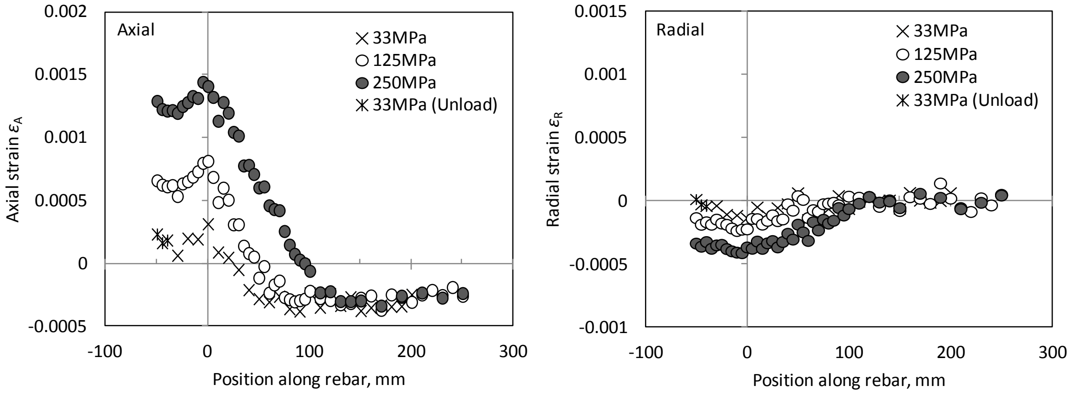

Fig. 1 Strain distributions along the rebar embedded in the concrete measured using neutron diffraction.

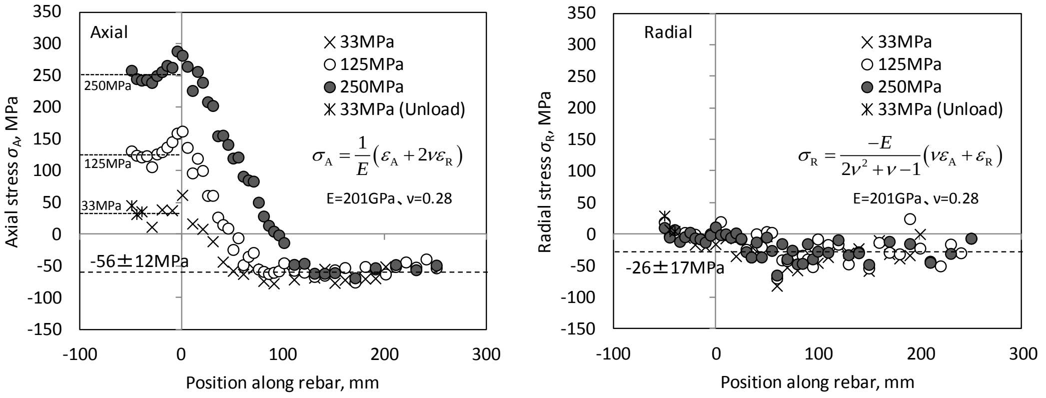

Fig. 2 Stress distribution along the rebar embedded in the concrete derived from strain distributions shown in Fig. 1.