A STUDY ON PREDICTING THE RESIDUAL LOAD CAPACITY OF ARCH ACTION

Chuo University Member ○Wei DONG
Nagaoka National College of Technology Member Yuki MURAKAMI
Chuo University Member Hideki OSHITA
Tokyo Electric Power Services co., LTD Member Shuichi SUZUKI
Tokyo Electric Power co., LTD Member Tomoaki TSUTSUMI

1. INTRODUCTION

Many built infrastructure facilities are deteriorating. One major reason is the corrosion of reinforcements, which often cause degradation to bond stress and propagate corrosion cracks. Residual load capacity of reinforced concrete is a long standing key problem, but it is not fully clarified. The better understanding in residual load capacity can lead to the improvement of both design method and maintenance of infrastructures. Moreover, it can make it possible to estimate the residual strength in future based on present environment. Recently, much attention is paid to arch action, which is an important mechanism to forming a system to predict the residual load capacity of corroded RC beams.

Based on this background, the objective of this study is to investigate the method of predicting the load capacity of corroded RC beams performing shear compression failure.

2. Experiment

In this study, the specimens are single reinforced rectangular RC beams with high tensile deformed steel bars. Fig. 1 shows the dimensions of the beams and the arrangement of reinforcements. There are 3 cases in all, and the detailed parameters are shown in Table 1. The mix proportion of concrete (design strength of 30MPa) and the mechanical properties of reinforcements are given in Table 2.

In order to protect the bond stress in anchorage from corrosion, only support span is corroded. Moreover, steel plates are fixed on the ends of beams to enhance anchorage performance. All the beams are tested with four-point flexural loading test, and load is applied at the speed of 0.5mm/min. The items to be measured are load, beam deflection and the axial strain of tensile reinforcement R. The major parameters include shear span to depth ratio and corrosion rate of tensile reinforcements which is evaluated by the ratio of corrosion weight loss.

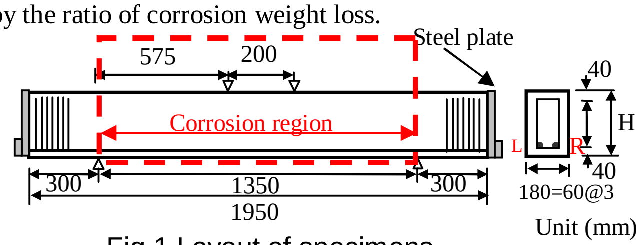


Fig.1 Layout of specimens

Table 1 parameters and results

Series	Specimen	a/d	H	Corrosion rate Aim (Reality)(%)	V_c (kN)	V_{exp} (kN)	Faliure mode	Notes
Case1	C1-1	2.4	280	−(−)	124.3	111.5	diagonal tesnion	uncorroded
	C1-2			−(−)		235.6	Shear compression	unbonded
	C1-3			5 (4.7)		184	Anchorage failure	corroded
	C1-4			10 (14.7)		172.3	Shear compression	corroded
	C1-5			20 (26.8)		161.1	Shear compression	corroded
Case2	C2-1	3.19	220	−(−)	88.8	100.8	diagonal tesnion	uncorroded
	C2-2			−(−)		123.1	Shear compression	unbonded
	C2-3			5 (4.5)		106.8	diagonal tesnion	corroded
	C2-4			10 (20)		114.3	Shear compression	corroded
	C2-5			20 (26.3)		98	Anchorage failure	corroded
Case3	C3-1	4.42	170	−(−)	69.6	62.8	diagonal tesnion	uncorroded
	C3-2			−(−)		61.4	Shear compression	unbonded
	C3-3			5(5)		58.5	Shear compression	corroded
	C3-4			10 (12.3)		81.1	Shear compression	corroded
	C3-5			20 (23)		51.6	Shear compression	corroded

Table 2 Material characteristics

(a) Mix proportion of concrete

Gmax (mm)	W/C (%)	SL (cm)	Air (%)	Unit weight (kg/m3)					
				W	C	S	G	Admixture	NaCl
20	60	10	5	168	280	826	996	2.8	8.8

(b) Reinforcement properties

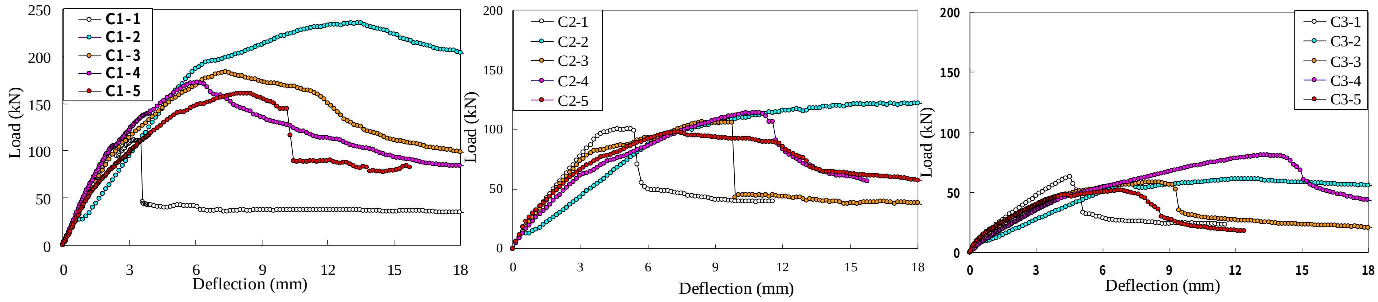
Nominal diameter	D6	D19	D22	D22
Specifications	SD345	USD685B	USD686B	SD345
Nominal Area(mm^2)	31.7	286.5	387.1	387.1
Yield stress (N/mm^2)	438	716	723	400
Tensile strength(N/mm^2)	557	901	930	579
Elasticmodulus(N/mm^2)	2.0×10^5			

3. RESULT

3.1 Corrosion pattern

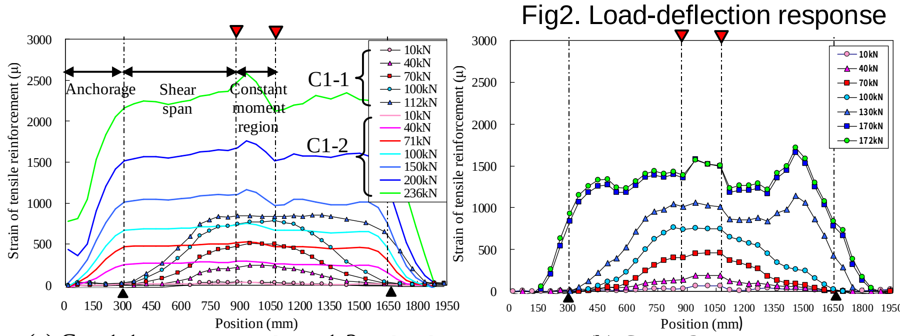
The corrosion rate of reinforcement of each beam is shown in Table 1. All the beams are uniformly corroded, and the high tensile deformed steel bars do not yield, even till the

Keywords: shear compression failure, arch action, load capacity, corrosion of reinforcement
Address Concrete Lab, Chuo University, 1-13-27 Kasuga, Bunkyoku, Tokyo 1128551 TEL 03-3817-1892



(a) Case1 (b) Case2 (c) Case3

Fig2. Load-deflection response



(a) Case1-1 (uncorroded) and case1-2 (unbond) (b) Case1-3 (corroded)

Fig3. Distribution of strain

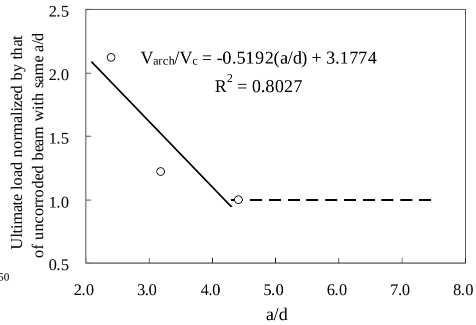


Fig4. Normalized load vs. a/d

beam fails. The corrosion cracks present along the tensile reinforcements and stretch in anchorage, but do not run through.

3.2 Failure mode

The ultimate load and the failure mode are shown in Table 1, the experimental load-deflection responses are shown in Fig. 2, and the distribution of strain is shown in Fig. 3. Many beams perform ductile failure owing to the steel plate. In this study, all the uncorroded beams perform diagonal tension failures, whereas unbonded beams and corroded beams perform shear compression failures (arch action). Fig. 3(b) shows the process of truss action shifts to arch action in corroded beams.

3.3 Influence of a/d on firm arch action

Fig. 4 shows the relationship between normalized ultimate load of unbonded beam V_{arch} (divided by V_{exp} of uncorroded beam with the same a/d) and span to depth ratio. It indicates the larger is the a/d, the firmer is the arch action. In other words, arch action is hard to occur in the beam with higher a/d, so the curve has a horizontal asymptote. There is a significant linear correlation among the data, and the approximate line can be drawn as shown in Fig. 4. Therefore load of firm arch action at any a/d can be predicted by below equation.

$V_{arch}/V_c = -0.52(a/d) + 3.18$ Eq. 1

3.4 Influence of corrosion on load of arch action

The relationship between normalized ultimate loads (divided

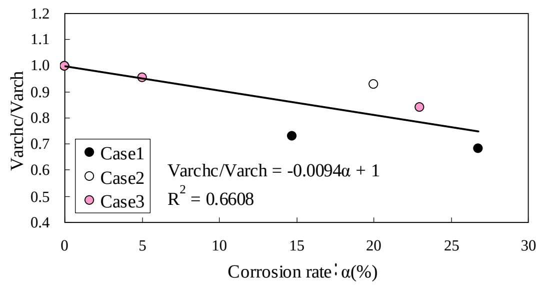


Fig5. Normalized load vs. corrosion rate

by V_{arch} with the same a/d) and reinforcement corrosion is shown in Fig. 5. It indicates normalized ultimate load behave linearly with respect to corrosion. Moreover, the linear equation 2 is shown below.

$V_{archcor}/V_{arch} = -0.0094\alpha + 1$ Eq. 2

Summarizing the equation mentioned above, the ultimate load of action of corroded beam can be predicted at a certain range of a/d and corrosion rate. The equation is shown below.

$V_{archcor} = (-0.0094\alpha+1)\ (3.18-0.52(a/d))\ V_c$ Eq. 3

4. Conclusions

1 Beam performs ductile failure owning to steel plates.

2 Arch action is easy to occur in beams with small a/d.

3 It is possible to predict the load capacity of corroded beam with high tensile deformed steel bars, which perform shear compression failures.

References

JSCE, (2006). "*Performance of corroded Concrete Structural*." *Concrete Engineering*, Tokyo: Japan Society of Civil Engineer