



A method to detect lap splice in reinforced concrete using a combination of covermeter and GPR

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HIGHLIGHTS

- An effective application of using combined covermeter and GPR is presented.
- A method to detect direction of rebars in the lap splices is proposed.
- A method to estimate summation of rebar diameter at a lap splice is proposed.

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ABSTRACT

A method to detect a lap splice and to estimate a summation of a diameter of the two rebars of the lap splice in reinforced concrete based on a combined utilization of covermeter and ground penetrating radar (GPR) is proposed. The performance of the proposed method is compared with the case that only one instrument is employed. The results show that the proposed method can detect the type of overlapping direction of the lap splice and estimate the summation of the diameter of the two rebars with an average error of 2.35% and standard error of estimate of 1.34 mm.

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1. Introduction

A lap splice is an overlapping of rebars in reinforced concrete (RC), mostly two rebars, to create a continuous line of rebar and is unavoidable due to the limited length of commercial rebars. When seismic performance is considered, locations of lap splices in RC structures must be carefully specified because lap splices might be located in the potential plastic hinge region of some bridge and building columns [1,2]. In Thailand, the Building Control Act [3], for the first time, recommended locations of lap splices in 1997. This means that RC structures built prior to 1997 must be checked whether lap splices are located in unsuitable positions or not. However, it is difficult to detect the locations and estimate the summation of the diameter of two rebars at a lap splice.

Well-known for its ability to detect a rebar in concrete, covermeter and ground penetrating radar (GPR) are non-destructive

tests (NDT) to locate the rebar, to measure cover thickness, and only for covermeter, to estimate the rebar size in RC structures [4]. Covermeter is defined by ACI-228.2R [5] as a common NDT method which applies the principle of eddy currents method. Coils in the probe are periodically charged by the current pulse and thus generate a magnetic field. On the surface of an electrically conductive material, which is in the magnetic field, eddy currents produce a secondary magnetic field that interacts with the field of the coil. Carino [6] studied the performance of covermeter and showed the possibility of using covermeter to estimate the length of lap splices by using the relative amplitude along the scan in longitudinal direction and presents the effect of closed-spaced rebars, multiple rebars on the accuracy of covermeter results. However, the classification of single bars and lap splices as well as the summation of the diameter of two rebars at a lap splice were not studied. This raises the question about the possibility of using covermeter to determine these issues.

GPR is frequently selected in real application due to its high penetrating capability, faster-scanning speed and ability to detect

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both metallic and non-metallic buried objects. There are several applications of GPR for RC structures. Its potential applications are summarized by Bungey [7]. The location of rebars and metallic ducts, and estimation of depth and element thickness from one surface in RC structures have received considerable attention over recent years and GPR has proved effective in these applications [8–11]. The application of GPR is not only limited to detecting and locating the metallic objects but it can still be used to estimate the diameter of rebars [12,13]. Moreover, a combination of covermeter with GPR can be used to extract locations of prestressing bars in multiple rebar layers [14].

In a typical case, the lap splice is created by overlapping two rebars with the same diameter to achieve a continuity of reinforcement in RC structures. Therefore, covermeter and GPR may detect the lap splice and interpret it as one rebar and error in the estimation of the diameter of rebars and cover thickness may occur.

In our previous study [15], we presented a method to determine the location of the rebar and the estimate the cover thickness as well as effects of the diameter of the buried object (steel pipes and rebars) on GPR data. In the experimental study, concrete and dry sand were used as the medium materials. The results show that the dry sand samples gave a smaller error when compared to the concrete medium and the effect of estimated cover thickness becomes more obvious when the diameter of the buried objects is larger than 45 mm (steel pipe). However, lap splices were not studied in our previous work.

In this article, effects of the lap splice in RC structures on covermeter and GPR data are studied. Data sets were experimentally obtained from rebars with/without the lap splice in dry sand and in concrete specimens. Varied test parameters were the diameter of the rebars and overlapping directions. A method to identify the type of the lap splice with different overlapping directions and to estimate a summation of the diameter of the two rebars by using a combination of covermeter and GPR is proposed. The results from the proposed method were also compared with the case that only one instrument, either covermeter or GPR, is employed.

2. Experimental study

2.1. Dry sand simulation tank

Fig. 1 shows the test setup for obtaining data of rebars in a dry sand simulation tank. Our experiment set up bears a close resemblance to the one previously proposed by the authors [15]. All rebars were deformed bars with diameters 12, 16, 20, 25, 28, and 32 mm. Cover thickness was fixed at 50 mm from the plastic sheet surface to the embedded rebar surface. Types of embedded rebar conditions were a single rebar, lap splices with the horizontal overlapping direction (HOD) and lap splices with the vertical overlapping direction (VOD) as shown in Fig. 1. Lap splices were made by overlapping two rebars with the same diameter of the rebar.

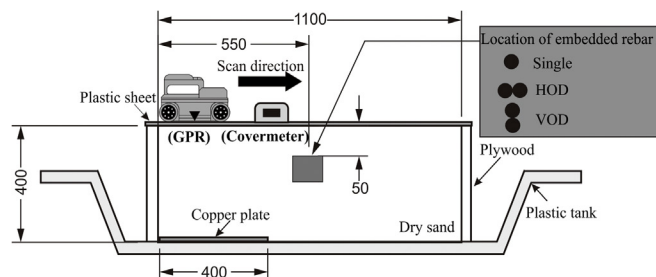


Fig. 1. Test setup of dry sand simulation tank and example of the lap splice in dry sand (unit: mm).

Table 1
Diameters and type of rebar in dry sand and concrete specimens.

Code	Diameter of rebar (mm)	Rebar type	Medium material
D12	12	Single bar	Dry sand, concrete
D16	16	Single bar	Dry sand, concrete
D20	20	Single bar	Dry sand, concrete
D25	25	Single bar	Dry sand, concrete
D28	28	Single bar	Dry sand
D32	32	Single bar	Dry sand
HOD12	12 + 12 (24) ^a	HOD ^b	Dry sand, concrete
HOD16	16 + 16 (32)	HOD	Dry sand, concrete
HOD20	20 + 20 (40)	HOD	Dry sand, concrete
HOD25	25 + 25 (50)	HOD	Dry sand, concrete
HOD28	28 + 28 (56)	HOD	Dry sand
HOD32	32 + 32 (64)	HOD	Dry sand
VOD12	12 + 12 (24)	VOD ^c	Dry sand, concrete
VOD16	16 + 16 (32)	VOD	Dry sand, concrete
VOD20	20 + 20 (40)	VOD	Dry sand, concrete
VOD25	25 + 25 (50)	VOD	Dry sand, concrete
VOD28	28 + 28 (56)	VOD	Dry sand
VOD32	32 + 32 (64)	VOD	Dry sand

^a The number in parentheses is the summation of the diameter of two rebars.

^b Horizontal overlapping direction.

^c Vertical overlapping direction.

Table 1 shows diameter and types of rebar conditions in dry sand and concrete specimens which were used in this study.

2.2. Concrete specimen

In order to compare the results obtained from the dry sand simulation tank with those from the real concrete specimens, concrete specimens were designed to incorporate a single bar and lap splices (HOD and VOD). All rebars were deformed bars with diameters 12, 16, 20, and 25 mm. Cover thickness was fixed at 50 mm. The details of all concrete specimens are shown in Fig. 2. Only specimens No. 2 and No. 3 were prepared to have lap splices with four different summations of the diameter of the two rebars and two overlapping directions (HOD and VOD). In all concrete specimens, the concrete used to cast the specimens was a ready-mixed concrete with the same mix proportion having a 28-day compressive strength of 35.5 MPa. Table 2 shows the mix proportion of the concrete.

2.3. Description of instrument

Two devices were used in this study. Covermeter is a Proceq model Profometer 5⁺ manufactured by Proceq UK limited and GPR device is a JRC model NJJ-105 (hand-held) system manufactured by Japan Radio Co., Ltd. with a central frequency of 1500 MHz as shown respectively in Fig. 3(a) and (b). For the covermeter, results consist of the signal value, the estimated cover thickness, and the estimated diameter of the rebar. The signal value is governed by the value of the applied voltage, the resistance, and another quantity called inductance. Covermeter data were recorded at every 10 mm along the scan axis. For the GPR device,



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