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APPLYING MOROCCAN METHOD FOR EVOLUTIONARY STUDY OF THE FLEXIBLE PAVEMENT DEFLECTION BASED ON THE LACROIX DEFLECTOGRAPH RESULTS.

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Abstract

At present, degradation surveys are often insufficient to detect the beginning of damage in thick structures. In addition, it has become necessary to complete them with deformation measurements in order to measure the deflection under the action of a heavy load that allows evaluating the pavement rigidity. These measurements are used on a local scale to estimate the residual life of a pavement or on a route scale to detect homogeneous or degraded areas. In Morocco, the LACORIX deflect graph is used to measure the vertical deformation (deflection) of a pavement under the axle of a heavy vehicle moving at constant speed. This technique is used to monitor road networks and study its evolution under traffic, to detect defective areas to be reinforced and to control the execution and efficiency of the reinforcements. In this regard, and in collaboration with the Moroccan National Center for Road Studies and Research, we propose in this paper a study of the deflections evolution basing on the data analysis related to the auscultations results. The studied section is part of the Moroccan National road number 06, composed of a flexible structure over a length of 50 km connecting the town of Meknes and Khemisset. The results obtained are reduced through a deformation matrix subdivided into four levels of deformation (A: very good, B: good, C: bad, D: very bad) for object of representing the bearing capacity evolution of this pavement using the Moroccan method.

Index Terms: Deflection, LACROIX Deflectograph, Moroccan Road, Moroccan, Road Inspection**.**

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1.INTRODUCTION

The surface deformability test remains a very relevant test for characterizing the pavement structure condition. Its interest has motivated a lot of research over the last 50 years, research that has led to profound changes in both the equipment and the procedures for performing and operating the test. Therefore, it became necessary to update and clarify the approach. The pavement deflection study has seen a remarkable evolution. For about fifty years, the surface deformability measurement has been the basic test to analyze the pavement structures behavior and to evaluate their capacity to support heavy traffic. This test was first implemented on an ad hoc basis with Benkelman beams [1]. In the 1960s, its use became more systematic with the appearance of the LACROIX deflectograph [2]. In the mid-1970s, maintenance study methodologies, well adapted to the case of flexible pavements, were widely applied [3], [4]. They gave a central place to the surface deformability measurement.

Many studies have dealt with pavement deformability by calculating pavement deflection. New uses of deflection basin measurements to characterize the structural condition of pavements and a methodology were therefore developed for the creation of indicators optimized to a specific type of defects [5]. The deflection was used for the programming of reinforcement and maintenance works [6]. Deflection was used to determine the structural index of an existing pavement structure [7]. In this article, we propose a quantitative and qualitative approach, based on an analysis of the results of the inscriptions carried out by means of a Lacroix Deflectograph in order to reduce the data obtained by means of a matrix of degradation developed by the Moroccan National Center for Road Study and Research (CNER) [8 article my]. These results are represented in format of qualitative variables of three deformation levels represented in the following table:

Table 1 : Defeormation Matrix Level

Deterioration class	Condition Index
A	Very Good
B	Good
C	Poor

2.DEFLECTION MEASUREMENT AND METHOD

2.1 Moroccan context

In the Moroccan context, the road network plays an essential role in the economic development, it includes 57 334 km of road length (highways, nationals, provincials and regional's roads) of which 45 240 km are paved. This road heritage is managed by the Ministry of Equipment, Transport, Logistics and Water, from which the National Center

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for Road Studies and Research (CNER) is responsible for the pavement monitoring and the road management systems development. In this regard, the deflection measurements are carried out by LACROIX deflectograph measurement [9] in order to collect the pavement structural deformations, the pathologies as well as the instantaneous state.

2.2 LACROIX Deflectograph Test

The deflection gives an indication of the bearing capacity and stiffness of a pavement. It is a decision criterion for the choice of reinforcement thickness and the evaluation of pavement quality. It is a test carried out by the Benkelman beam with a comparator, and carried out in accordance with the requirements of standard NF P 98 200-2. It consists in measuring at a given point on the roadway the deflection caused by a rolling load by taking the value of deflection indicated on the comparator. The measurements are carried out under a load of 13 tons using a deflectograph Lacroix (Fig. 1.) according to the LCPC n39 test methods and the NFP 98.200.1 to 98.200.7 [10].

Figure 1: LACROIX Deflectograph

To perform the measurements, the frame on which the two probe arms are fixed between the rolling tracks in the space between the axles of the test vehicle. The truck drives at a constant speed (approx. 3 to 8 km/h). The frame remains stationary on the road until the rear axle is 10 cm above the measuring point of the arms. Thus, Lacroix registers a deflection pool of 65 measuring points in each wheel track. The system moves on to the next measuring point (4 to 6 m away) by pulling the measuring frame with a winch (Lacroix Classic) at 3 km/hl or by lifting the frame (Lacroix Flash) at 8 km/hl without stopping the vehicle. The measuring principle is presented in figure 2.

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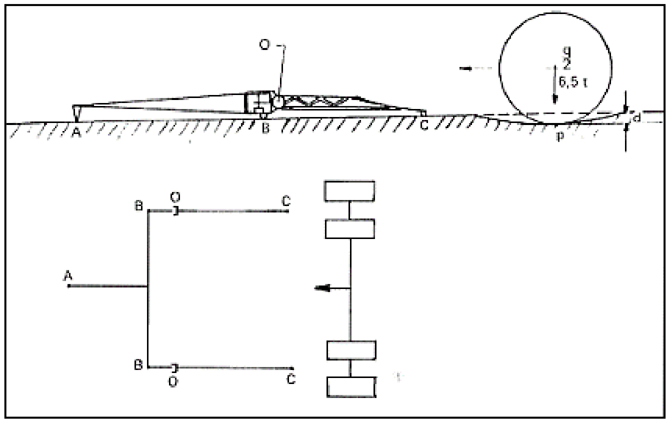
Figure 2: LACROIX Deflectograph



The deflection is measured between each pair of the vehicle's rear axle by feeler arms equipped with rotating sensors and articulated on a reference beam. This reference beam, detached from the vehicle, rests on the roadway at three points located outside the load's influence zone. As the vehicle moves forward, the deflection is recorded until the couplers reach the level of the sensors. The reference beam is then taken over by the vehicle, brought forward, and put back on the road in its initial position towards the vehicle, for a new measurement, without the vehicle interrupting its movement. The correlation with static deflection measurements (by means of sensors anchored in the pavement) is very good, even for very low pavement deformations. The deflectograph characteristics [11], used in the current work, are shown in table .2 below:

Table 2: Deflectograph Characteristics

characteristics	LACROIX Deflectograph
Load application method	Rolling load
Speed of load application	10 km/h (5Hz)
Performance (routine measurements)	2 to 3 Km/h (Classic Lacroix)
the measuring step	4 to 6 m (Lacroix Flash)
Resolution of the measuring sensor	1/100 mm
Location of measurements	Wheel track: Left and right
Deflection basin measurement	Real basin for flexible pavements /65 points
Loading level applied for a measurement	Single (50 KN or 65 KN - axle 10 t or 13 t)
Type of superstructures inspected	Flexible pavements [12]

The Lacroix deflectometer stresses the structure in such a way that it generates greater amplitude of deflection that varies more slowly. This loading mode is compatible with an inductive sensor measuring the displacement at V100 of mm. The deflection measurements provided by Lacroix are used as a basis for an evaluation of the load-bearing capacity of the tested structure and thus the verification of pavement structural condition.

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2.3 Method: Deformation matrix

The deflection measured by the deflectograph gave results on each 1 kilometer long step. This reflects 50 variables in our case study. To understand the data evolution, we have used a matrix developed by the Moroccan Center for Road Studies and research, to reduce and classify the data. This matrix is based on the measured deflection, the traffic and the degradation state. The latter is represented in the form of qualitative variables: A (very good), B (good) and C (poor). The following figure shows the matrix used:

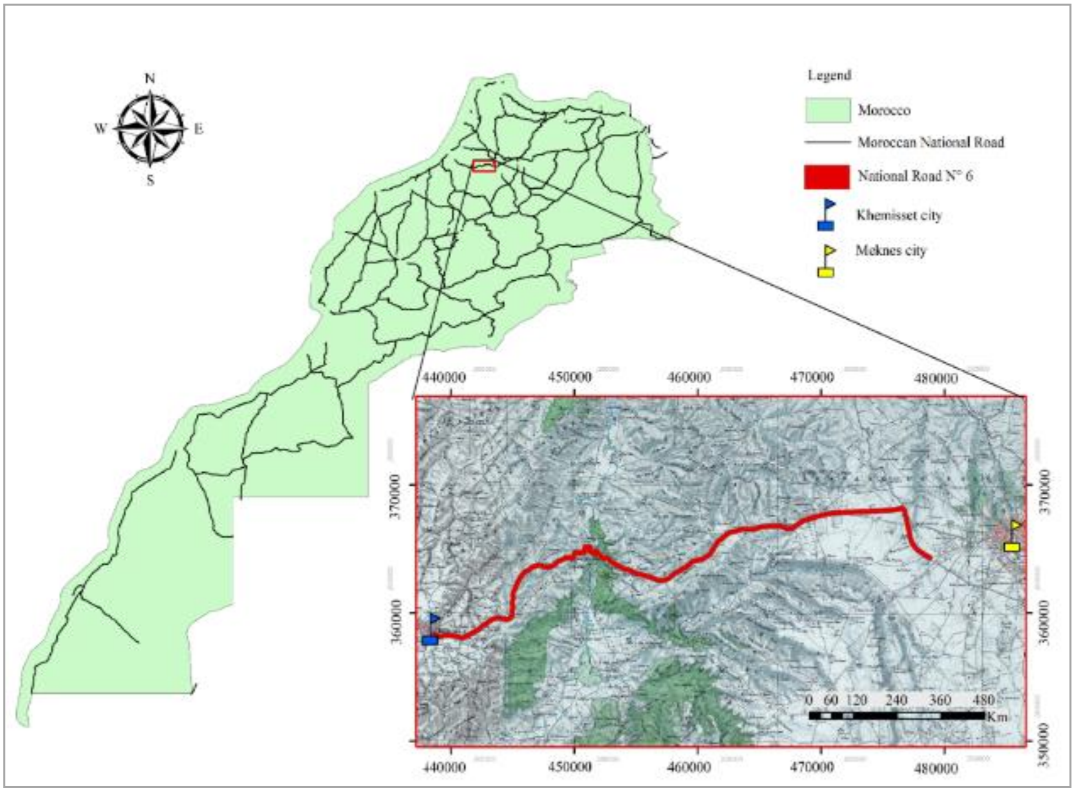
Table 3: Deflection Matrix

Deflection (1/100)				
Deterioration Class	**T0**	**T1**	**T2**	**T3-T4**
A	<80	<100	<120	<140
B	[80 ,120[	[100,140[	[120,160[	[140,180[
C	>=120	>=140	>=160	>=180

2.4 Research significance

The study section is composed of a flexible pavement, with a length of 50 km connecting the city of Meknes and Khemisset. The inspections were carried out every 2 years by the CNER, in order to quantify the quality of the pavement bearing capacity from the kilometer point starting KP 0+080 to KP 0+130. The study location is at (439617, 099607; 358252, 3626787) to (478570, 08923; 364436, 6971297). The following figure represents the location of the study section.

Figure 3: Location of study section



The research objective is to study the evolution of the section under study through reducing the data obtained between the year 2008 and 2018. The methodology synthesis is represented in the following figure:

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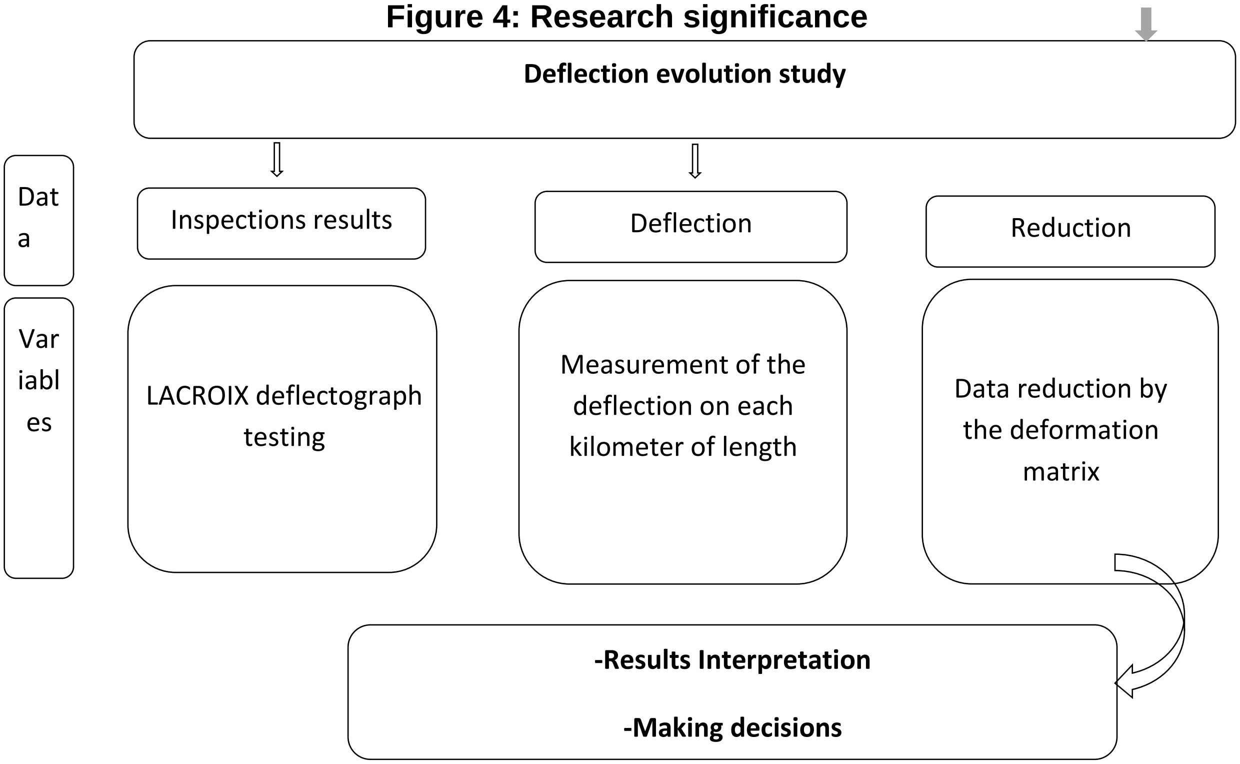
Figure 4: Research significance



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3.RESULTS AND DISCUSSION

The results obtained from the data reduction are represented in the following table:

Table 4: Data Reduction Results

KP (Stat)	KP (End)	Deflection 2008	Deflection 2010	Deflection 2012	Deflection 2014	Deflection 2016	Deflection 2018
80	81	A	A	A	B	C	C
81	82	A	A	A	B	A	A
82	83	A	A	A	A	A	A
83	84	A	A	A	A	A	A
84	85	A	A	A	C	A	A
85	86	A	A	A	A	A	A
86	87	A	A	A	A	A	A
87	88	A	A	A	A	A	A
88	89	A	A	A	A	A	A
89	90	A	A	A	A	A	A
90	91	A	A	A	A	A	A
91	92	A	A	A	A	A	A
92	93	A	A	A	A	A	A
93	94	A	A	A	A	A	A
94	95	A	A	A	A	A	A
95	96	A	A	A	A	A	A
96	97	A	A	A	A	A	A
97	98	A	A	A	A	A	A
98	99	A	A	A	A	A	A
99	100	A	A	A	A	A	A
100	101	A	B	A	A	A	A
101	102	A	B	A	A	A	A
102	103	A	B	A	A	A	A
103	104	A	A	A	A	A	A
104	105	A	A	A	A	A	A
105	106	A	A	A	A	A	A
106	107	A	B	A	A	A	A
107	108	A	C	A	A	A	A
108	109	A	C	A	A	A	A
109	110	A	A	A	A	A	A
110	111	A	A	A	A	A	A
111	112	A	B	A	A	A	A
112	113	B	B	B	A	A	A
113	114	B	B	B	A	A	A
114	115	B	B	A	A	A	A
115	116	B	B	A	A	A	A
116	117	A	B	A	A	A	A
117	118	B	B	A	A	A	A
118	119	B	B	A	A	A	A
119	120	B	B	A	A	A	A
120	121	B	B	A	A	A	A
121	122	B	B	A	A	A	A
122	123	A	B	A	A	A	A
123	124	B	B	A	A	A	A
124	125	B	A	A	A	A	A
125	126	B	A	A	A	A	A
126	127	B	A	A	A	A	A
127	128	B	A	A	A	A	A
128	129	B	A	A	A	A	A
129	130	B	B	A	A	A	A

Analyzing the results obtained from the data reduction, the deflection has known a remarkable change along the 50 kilometers studied. This confirms the imperative

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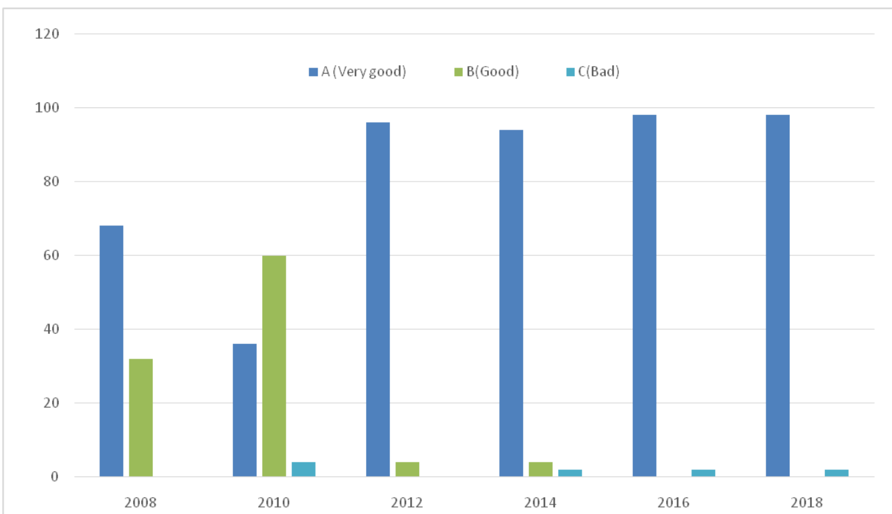
change of the structural state on several sections. The applied method clearly served to separate the road into homogeneous and heterogeneous sections. In 2018, the road has known a certain stability of the condition considered acceptable with a percentage in indicator A of 68%, 32% of B with absence of class C. These values were decreased in 2010, with the presence of the class C deformation on a length of 2 km that represents 4% of the total length studied. This variation has pushed the CNER to program several maintenance actions. These have kept a very remarkable bearing capacity during the following two years, which is confirmed by the absence of type C deformations with a remarkable presence of level A with a percentage of 96%. In 2014, 2016 and 2018 the percentage of the A+B indicator kept a stable value (96%) with the appearance of the C indicator in two sections: from KP 84 to KP 85 and from KP 0+080 to KP 0+081. The following figure represents the evolution of the bearing capacity between the year 2008 and 2018:

Figure 5: Graphical representation of the evolution of deflection between the year 2008 and 2018



The bearing capacity of this pavement was remarkably stable throughout the survey period, except for some variations due to the evolution of traffic, soil changes, geology and climate of the region. However, the usage of the Lacroix Deflectograph as a decision support tool confirms that it represents an essential support to geolocate the most degraded sections on the one hand, and to study the evolution of the bearing capacity along the study period on the other hand. This study has also shown the reliability of the matrix developed by CNER to reduce the deflection data on the one hand, and on the other hand to quantify the most unfavourable sections. This leads to a rapid optimization of the time to deduce the possible future actions. In this regard, we propose the following:

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-Reinforcing the following sections: from Pk 0+080 to Pk 0+081, and from Pk 0+084 to Pk 0+085.

-Preparing preventive actions by carrying out complementary geotechnical studies in the field,

-Study the preventive evolution of the bearing capacity, in order to prevent future possible scenarios on the one hand, and to optimize the maintenance costs on the other hand.

4.CONCLUSION AND PERSPECTIVES

Managing road assets, optimizing maintenance costs, while maintaining pavement performance, are key subjects for road decision makers today. This article presents a quantitative and qualitative approach based on the classification of the pavement deflection results obtained from tests performed with a LACROIX Deflectograph. The approach was aimed at applying a deformation matrix developed by CNER for the data reduction on the one hand, and to deduce the weaknesses areas on the other hand.

The method has shown its reliability in terms of geo location and rapidity to deduce the damaged sections and to propose actions for maintenance and repair from the analysis of homogeneous and heterogeneous sections. This section is subject to traffic, environmental and climate change constraints, which introduce structural deterioration, however, under and over-dimensioning can indirectly affect the homogeneity and stability of the pavement layers.

In perspective, on this same section, the study will be completed by the study of the evenness using a longitudinal profile analyzer, in order to evaluate the interaction between the deflection and the evenness, to deduce the structural indicator, and to prevent the future evolution.

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REFERENCES

[1] LACROIX J. (1963), Déflectographe pour l'auscultationrapide des chaussées, Bulletin de liaison des Laboratoires des PontsetChaussées, 3, sept., pp. 191.1-191.16.

[2] NORET H. et al. (1965), Le déflectomètreLacroix, version 1964, Bulletin de liaison des Laboratoires des Ponts et Chaussées, 11, janv., pp. 1.1-1.28.

[3] AUTRET P. (1972), Évolution du déflectographeLacroix :pourquoi ?, Bulletin de liaison des Laboratoires des Ponts et Chaussées, 60, juil., pp. 11-17.

[4] ROUTES ET DEVELOPPEMENT - COMPTES RENDUS DU COLLOQUE INTERNATIONAL,PARIS,22-

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
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DOI 10.17605/OSF.IO/D4N23

25 MAI 1984 Volume: 1 Publisher: PRESSES DE L'ECOLE NATIONALE DES PONTS ET CHAUSSEES

[5] Rohde, G. T. (1994). Determining pavement structural number from FWD testing. Transportation Research Record, (1448).

[6] Le Boursicaud, V. (2018). Nouvellesutilisations des mesures de bassins de déflexion pour caractériserl'étatstructurel des chaussées (Doctoral dissertation, Ecolecentrale de Nantes).

[7] Mehdi, M. A., Cherradi, T., Qachar, M., &Chigr, A. (2021). Analysis of structural and surface deteriorations of a flexible pavement, based on inspection results using the MCA method. Materials Today: Proceedings, 45, 7538-7546.

[8] méthoded'essai LPC n 39, Etudes routières, déformabilité de surface des chaussées; exécution et exploitation des mesures, laboratoire central des ponts et chaussées 1997

[9] Henia, M.O. and Braber, R. Falling Weight DeflectometeretDéflectographeLacroix: Comparaison, Domained'Application et Perspectives. (2008) Suisse, 6 p.

[10]méthoded'essai LPC n 39, Etudes routières, déformabilité de surface des chaussées; exécution et exploitation des mesures, laboratoire central des ponts et chaussées 1997

[11]Mohammed Amine Mehdi, Cherradi, T. ., Bouyahyaoui, A., El Karkouri, S., & Qachar, A. (2022). EVOLUTION STUDY OF THE PAVEMENT STRUCTURAL INDICATOR BASED ON EVENNESS AND DEFLECTION RESULTS USING A GIS TOOL MAPPING. GEOMATE Journal, 23(95), 144–153.

[12]National Research Council National Academy of Sciences, National Academy of Engineering Standard, Standard Nomenclture and Definitions for Pavement Components and Deficiencies, Nomenclature and Definitions for Pavement and Dficiencies, HRB, USA, JUN 1970.