ABSTRACT

The use of survey control networks is one of the most important techniques applied in deformation monitoring field. The differences in coordinates of stations (displacements) obtained from least squares adjustments are compared in order to assess if a deformation of a specified magnitude exists.

In this research the well known methods of deformation detection are reviewed. Traditionally, the global congruency test is carried out to detect if the area of the network have undergone any change in shape and, as a next step, localization methods are applied to determine deformations at specific points.

However, the localization procedures developed are rather complicated and tedious. A new method is developed to detect deformations at specific points directly without the need for further localization techniques. The procedure is used both directly and sequentially using fixed and free networks.

The results obtained from the direct application of the method are identical up to 75% when compared with those obtained from the old techniques. The sequential procedure gave results that are 100% identical to those obtained from the old methods.

Results, also, indicate that the variation of an observation more than twice its standard error leads to a detectable deformation at a level of significance greater than 0.05.

Vertical deformations can be represented graphically using contour lines. This idea is applied to detect the vertical deformations and to define the stable area using the statistical results of the new procedure.

□□□□□□

تُستخدم شبكات الضبط في المساحة كواحدةٍ من أهم تـ قنيات إكتشاف الإزاحة لموا قع الن قاط المحددة علي سطح الأرض . بعد الحصول علي الـ قياسات النسبية لهذه الن قاط, علي فترات زمنية مختلفة, تتم المـ قارنة للإحداثيات المحسوبة لن قاط الشبكة الأرضية عن طريق نظرية أ قل التربيعات لغرض تحديد مـ قدار الإزاحة أو الحركة لهذه الن قاط.

فى هذا البحث تمت مراجعة بعض الطرق المستخدمة فى إكتشاف الإزاحة. لـ قد جرت العادة علي إستخدام الإختبار الشامل (the global congruency test) لجميع نـ قاط الشبكة لتحديد ما إذا كان هنالك إزاحة كلية لموا قع نـ قاط الشبكة كنتاج للعوامل الطبيعية أوالحضارية . يُتبع هذا الإختبار بأحد الإختبارات المحلية(Localization) لتحديد مـ قدار الإزاحة عند كل نـ قطة على حدة في حالة وجود تغير عام في الشكل.

كما انه معلوم ان هذه الاختبارات المحلية معـ قدة وشا قة فى تطبيـ قاتها. تم تـ قديم طريـ قة (تـ قنية) حديثة, في هذا البحث, لتحديد مـ قدار الإزاحة وإكتشافها, إحصائيـاً مباشرةً فى الن قاط بصفةٍ فردية من غير اللجوء لهذه الاختبارات المحلية. تم تطبيق هذه النظرية مباشرةَ وتتابعياً على شبكات الضبط الثابتة والحرة.

وُجد أن نتائج التطبيق المباشر لهذه النظرية مطابق بنسبة تصل الى 75% بالمـ قارنة مع تلك التى أعطيت بواسطة التـ قنيات المستخدمة فى هذا المجال. كما أن تطبيق هذه النظرية تتابعياً قد أعطى نتائج مطابـ قة للطرق المستخدمة بنسبة 100%.

تُوضح النتائج أيضا أن التغيَر فى الأرصادات بمـ قدارالضعف, أو أكثر, للخطأ المعيارى لها يؤدى الى إزاحة مُكتشفة عندما تستخدم نسبة إحتمال لو قوع خطأٍ من النوع الأول (α) لا تـ قل عن 5% .

كما يمكن إستخدام خطوط الكفاف (الكنتور) لتمثيل الإزاحة الرأسية بيانياً , أيضاً ,يُمكن إستخدام هذه الطريـ قة مع النتائج الإحصائية للنظرية الحديثة لغرض إكتشاف الإزاحة بيانياً.

ACKNOWLEDGMENTS

First my thanks is to ALLAH
who gave me soul, health and mind.
I wish, also, to express my gratitude to
Dr. Ali Hasan Fagir and
Dr Ahmed Mohammed Ibrahim
for their attention and good guidance
to introduce this research.
Finally thanks to my father, mother and my wife.

LIST OF CONTENTS

Abstract	i
Acknowledgements	iii
List of Contents	iv
List of Tables	vii
List of Figures	x
Chapter One: Introduction	
1.1 General	1
1.2 Objectives of the Research	4
1.3 Layout of Contents	5
Chapter two: Adjustment of the Free Datum Networks	
2.1 Introduction	6
2.2 Datum for Survey Control Networks	6
2.2.1 Datum Parameters	7
2.2.2 Datum Constrains	8
2.2.3 Coefficients Matrix for Full Datum Constrains(S)	10
2.3 Adjustment of the Free Datum Network	12
2.3.1 Generalized Inverse of the Normal Equations Matrix	13
2.3.2 The General Solution	17
2.3.3 The Minimum Trace Solution	18
2.3.4 The minimum Norm Solution	20
2.3.5 General Remarks	21
2.4 Datum Transformation	22
Chapter Three: Design of Deformation Networks	
3.1 Introduction	25
3.2 Measures and Criteria for Precision	28
3.2.1 Measures of Precision	28
3.2.1.1 Global Measures of Precision	28
3.2.1.2 Local or positional Measures of Precision	29
3.2.2 Criterion Matrices	29

3.2.3 Datum Transformation of the Criterion Matrix 30
3.3 Measures and Criteria for Reliability 31
3.3.1 Measures of Reliability 32
3.3.1.1.Global Measures of Internal Reliability 33
3.3.1.2 Local measures of Internal Reliability 33
3.3.1.3 Global Measures of External Reliability 34
3.3.1.4 Local Measures of External Reliability 35
3.3.2 The Optimality of Design and Criteria for Reliability 35
3.4 Measures and Criteria for Sensitivity 36
3.5 Measures and Criteria for Economy 39
3.6 Methods of Deformation Networks Design 40
3.6.1 Computer Simulation 40
3.6.2 Analytical methods 41
3.6.2.1 Models Using the Inverse of the Criterion Matrix (C_c^{-1}) 41
3.6.2.2 Models Using the Criterion Matrix Itself (C_c) 42
3.7 Summary for the Design Procedure 43
Chapter Four: A New Strategy for Deformation Monitoring
4.1 Introduction 44
4.2 Deformation Measurements 44
4.2.1 Geodetic Methods 45
4.2.1.1 Terrestrial Geodetic Methods 46
4.2.1.2 Photogrammetric Methods 46
4.2.1.3 Space Techniques 46
4.2.2 Non-geodetic Methods 47
4.3 Adjustment of Deformation Networks 47
4.3.1 Indirect (Coordinates) Approach 48
4.3.1.1 The Single Epoch Adjustment 48
4.3.1.2 The Combined Adjustment 49
4.3.2 Direct (Observations) Approach 51
4.4 Deformation Detection 53
4.4.1 Absolute Monitoring Control Networks 54
4.4.2 Relative Monitoring Control Networks 54
4.4.3 Methods of Deformation Detection 55

4.4.3.1 The Global Congruency Test 55
4.4.3.2 Localization Methods 56
4.4.3.2.1 Localization with Implicit Hypothesis 56
4.4.3.2.2 Localization with Gauss Elimination 58
4.4.4 A New method for Deformation Detection 59
Chapter Five: Deformation Modeling Methods
5.1 Introduction 60
5.2 Deformation Modeling 60
5.2.1 Types of Deformation Models 61
5.2.1.1 Time Independent Models 61
5.2.1.2 Time Dependent Models 63
5.2.2 Examples of Deformation Models 64
5.2.2.1 Rigid Body Displacement Model 65
5.2.2.2. Homogeneous Strain or Rotation model 66
5.2.2.3 Homogeneous Strain and Relative Displacement Model 67
5.2.3 The Strain Model 68
5.2.4 Estimation of Deformation Parameters 70
5.2.5 Statistical Testing of Estimated Parameters 72
5.3 Graphical Representation of Displacements 73
5.3.1 Representation of Vertical Displacements 73
5.3.2 Representation of Horizontal Displacements 74
Chapter Six: Tests and Results
6.1 Vertical Deformation Networks 77
6.1.1 Fixed Datum Adjustment 79
6.1.1.1 The Global Congruency Test 80
6.1.1.1.1 Analysis of Results 80
6.1.1.1.2 Conclusions 80
6.1.1.2 Detection of Deformation Using the New Procedure 81
6.1.1.2.1 Analysis of Results 82
6.1.1.2.2 Conclusions 83
6.1.2 Free Datum Adjustment 83
6.1.2.1 The Global Congruency Test 83
6.1.2.1.1 Analysis of Results 84

6.1.2.1.2 Conclusions 84
6.1.2.2 Localization of Deformation 84
6.1.2.2.1 Analysis of Results 86
6.1.2.2.2 Conclusions 87
6.1.2.3 Detection of Deformation Using the New Procedure 87
6.1.2.3.1 Analysis of Results 89
6.1.2.3 2 Conclusions 89
6.1.2.4 Sequential Application of the New Method 89
6.1.2.4.1 Analysis of Results 92
6.1.2.4.2 Conclusions 92
6.2 Examples of Two Dimensional Deformation Networks 93
6.2.1 Fixed Datum Adjustment 97
6.2.1.1 Application of the New Procedure and the Global Test 98
6.2.1.2 Analysis of Results 99
6.2.1.3 Conclusions 100
6.2.2 Free Datum Adjustment 100
6.2.2.1 Application of the New Procedure and the Global Test 100
6.2.2.2 Analysis of Results 102
6.2.2.3 Conclusions 103
Chapter Seven: Conclusions and Recommendations
7.1 Conclusions 104
7.2 Recommendations 105
References 106
Appendices
Appendix A: Numerical Examples for Datum Defect Solution 110
Appendix B: Computer Programs for deformation detection 118
Appendix C: Deformation Monitoring with Graphical Methods 138
Appendix D: Statistical Tables 145

LIST OF TABLES

Table (2.1)	Datum Parameters of Survey Control Networks	8
Table (6.1)	Simulated Observations of the First epoch	77
Table (6.2)	Results of Four Epochs Observations	79
Table (6.3)	Displacements and Their Standard Deviations from the Four Epochs	79
Table (6.4)	Results of the Global Test for all Epochs	80
Table (6.5)	Results of Epoch (2)	81
Table (6.6)	Results of Epoch (3)	81
Table (6.7)	Results of Epoch (4)	82
Table (6.8)	Results of Epoch (5)	82
Table (6.9)	Displacements and Their Standard Deviations from the Four epochs	83
Table (6.10)	Results of the Global Tests	84
Table (6.11)	Contributions of Points Deformations to the Global Test Statistic	85
Table (6.12)	Contributions of Points Deformations after Point(1) is Excluded	85
Table (6.13)	Contributions of Points Deformations after Points(1&7) are Excluded	86
Table(6.14)	Contributions of Points Deformations after Points(1,7&6)are Excluded	86
Table (6.15)	Results of Individual Test for Epoch(2)	87
Table (6.16)	Results of Individual Test for Epoch(3)	88
Table (6.17)	Results of Individual Test for Epoch(4)	88
Table (6.18)	Results of Individual Test for Epoch(5)	89
Table (6.19)	Results of the New Procedure Using Displacements of all Points	90
Table (6.20)	Results of the New Procedure After Point(1) is Excluded	90
Table (6.21)	Results of the New Procedure After	

	Points(1&7) are Excluded	91
Table (6.22)	Results of the New Procedure After Points(1,7&6)are Excluded	91
Table (6.23)	Observed Distances and Their Standard Deviations	94
Table (6.24)	Observed Angels and Their Standard Deviations	94
Table (6.25)	Observed Directions and Their Standard Deviations	95
Table (6.26)	Observed Distances for the Four Epochs	95
Table (6.27)	Observed Angels for the Four Epochs	96
Table (6.28)	Observed Directions for the Four Epochs	96
Table (6.29)	Approximate Coordinates of the Networks Points	97
Table (6.30)	Easing and Northing Displacements of Points from the Four Epochs	97
Table (6.31)	Results of Deformation Test for Epoch(2)	98
Table (6.32)	Results of Deformation Test for Epoch(3)	98
Table (6.33)	Results of Deformation Test for Epoch(4)	99
Table (6.34)	Results of Deformation Test for Epoch(5)	99
Table (6.35)	Easting and Northing Deformations of Points from the Four Epochs	100
Table (6.36)	Results of Deformations Test for Epoch (2)	101
Table (6.37)	Results of Deformations Test for Epoch (3)	101
Table (6.38)	Results of Deformations Test for Epoch (4)	102
Table (6.39)	Results of Deformations Test for Epoch (5)	102
Table (A.1)	Observations of the Vertical Network	109
Table (D.1)	Normal Distribution	145
Table (D.2)	F-distribution with 5% Level of Significance	146
Table (D.3)	F-distribution with 1% Level of Significance	147
Table (D.4)	Percentiles od χ^2-distribution	148
Table (D.5)	Percentiles of t-distribution	149

LIST OF FIGURES

Fig (5.1)	Rigid Body Displacement	66
Fig (5.2)	Rotation of the Block	66
Fig (5.3)	Rotation and Relative Displacement of Blocks	67
Fig (5.4)	Confidence Ellipses of Displacements at Points i and j	75
Fig (6.1)	Simulated Vertical Network	78
Fig (A.1)	Vertical Control Network	108
Fig (C.1)	Deformation Lines from Epoch 4 Using Fixed Datum Adjustment	138
Fig (C.2)	Deformation Lines from Epoch 4 Using Free Datum Adjustment	139
Fig (C.3)	Graphical Detection of Deformations from Epoch (4) Using Fixed Datum	140
Fig (C.4)	95%Confidence Ellipses of Displacements from Epoch(3) Using Fixed Datum	141
Fig (C.5)	95%Confidence Ellipses of Displacements from Epoch(4) Using Fixed Datum	142
Fig (C.6)	5%Confidence Ellipses of Displacements from Epoch (3) Using Free Datum	143
Fig (C.7)	95%Confidence Ellipses of Displacements from Epoch (4) Using Free Datum	144
Fig (D.1)	Area Under the Normal Distribution Curve	145
Fig (D.2)	F-distribution Curve	146
Fig (D.3)	χ^2-distribution Curve	148
Fig (D.4)	t-distribution Curve	149