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Bible binding techniques: Analysis of spine lining constructions and endpaper reinforcements

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Bible Binding Techniques:

Analysis of Spine Lining Constructions and Endpaper Reinforcements

by

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MASTER'S THESIS

This is to certify that the Master's Thesis of

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ABSTRACT

The Bible has been the largest selling book title in the world. However, very little research of Bible binding techniques has been done. Most Bibles contain more than two thousand pages of Bible paper. Therefore, such books are usually thick and heavy. Thin bible papers provide very little strength for the joint.

The strength and durability of a bound product depends on good joint adhesion. The goal of this study was to investigate various joint constructions between the cover and the bookblock of Smyth-sewn Bible bindings. The spine lining and endpaper reinforcement are two most important factors of joint construction. Loose back and tubular lining are techniques used to reinforce adhesion of the bookblock to the cover. Whipstitched signature and hinged endpaper are two major endpaper reinforcement techniques of Bible bindings.

78 Bibles were tested utilizing UBT tumble test, Hinge-pull test, and Page-pull test. The books were approximately 6" x 9" in size, weighed three pounds using the same Bible papers. The results were analyzed by a two-way ANOVA with optional Duncan Multiple-Range Test at a 95% confidence level, and compared with the hypotheses concerning

bookbinding strength and durability. Furthermore, graphical analyses were made by plotting treatment means for each tests.

Firstly, it was questioned if there were any significant differences in the Smyth-sewn hardcover Bible binding strength between the different spine lining constructions of loose back and tubular liner. The statistical analysis and the graphical analysis of UBT tumble test results indicated that there was evidence of extreme differences in durability due to spine lining constructions, and that books constructed with tubular liner looked to be much more durable than books constructed in loose back. On the contrary, the analyses of Hinge-pull test results revealed that there was no significant variability due to spine lining constructions. This considerable discrepancy would result from the nature of the test methods and the nature of materials used. It seemed that in each tests, the stresses and forces distressed the tubular liner materials in the different ways to make them fail during testing. However, the UBT tumble test is considered to have shown and given the best correlation to the physical breakdown of books in actual use. Thus it would be reasonable to conclude that tubular liner constructions are assumed to increase binding durability as compared to loose back constructions.

Secondly, it was questioned if there were any significant differences in the strength of Smyth-sewn hardcover Bible bindings between the different endpaper constructions of four-page tipped-on endpaper, hinged endpaper, and whipstitched signature. The statistical and graphical analyses of UBT tumble test and Hinge-pull test indicated that there was evidence of significant differences in durability among three different endpaper constructions, and that books constructed with hinged endpaper reinforcement was more durable than books constructed with four-page tipped-on endpaper and whipstitched signature. Surprisingly the most inferior endpaper construction in durability was whipstitched signature reinforcement construction. Whipstitching resulted in the highest page-pull values, but it seemed to make the first and last signature areas relatively stiff so that, if tumbled, destructive forces and stress took havoc with the poorly flexing hinges.

The books which were bound with hinged endpaper reinforcement (for both spine lining constructions of tubular liner and loose back) and the books which were bound with four-page tipped-on endpaper and tubular liner showed a significant superiority in binding strength and durability to others.

Chapter 1

INTRODUCTION

According to Estimated Book Publishing Industry Sales Information[1] from the Association of American Publishers 1987 Annual Statistics, the sales of Bibles, testaments, and hymnbooks was $210.7 million out of total book sales of $11.4 billion in 1987. This represented a 15.2% increase over 1986 sales figure of $182.9 million. The Bible itself has been the largest selling book title in the world. However, very little research of Bible binding techniques has been done. Bible binding is a style of bookbindings using a lightweight bible paper used for Bibles, dictionaries, etc.

Pochinchai Printing Co., Ltd., which I have been working for since 1986, is one of the largest Bible printing and binding companies in Korea. The company has produced Smyth-sewn Bibles for many foreign publishers including American. The majority of quality Bibles is Smyth-sewn. Smyth-sewn binding is known as a sewn-through-the-fold binding. It is a method in which the folded leaves of a signature are first sewn, then subsequent signatures are sewn to the next one until the book is complete. Pochinchai

Printing Co., Ltd. showed great interest and support to this study of Smyth-sewn Bible binding techniques.

Book manufacturing is a complex technology. Bound and printed products should be manufactured to a standard appropriate for their designated end-use. The strength and durability of a bound product depends very much on good joint adhesion.[2] In order to discuss joint adhesion, one must be aware of how bookblocks are constructed and how each type may have different requirements for optimum linkage with the cover.

Most Bibles contain more than two thousand pages of Bible paper, therefore, such books are usually thick and heavy. The bulk and heavy weight of the bookblock can cause excessive strain in the joint areas. Furthermore, a thin Bible paper itself provides very little strength for the joint. Bible paper is a very lightweight and highly opaque paper, used primarily where low bulk is important. Its basis weight generally ranges from 14 to 30 pounds(25"x38"-500sheets).[3]

The goal of this study was to investigate various joint constructions between the cover and the bookblock of Smyth-sewn Bible bindings, which are spine lining and endpaper constructions. Loose back and tubular lining are techniques used to reinforce adhesion of the bookblock to the cover.

Loose back binding is a style of binding in which the spine binding material is not glued to the binding edge of the text sheets.[4] Tubular lining consists of a flat tube which is glued to the spine of the book block, and to the in-lay of the covers.[5] Four-page tipped-on endpaper construction has a four page endpaper tipped to the first or last part of a text block only by a thin line of adhesive.[6] Hinged endpaper and whipstitched signature are two major endpaper reinforcement techniques. Hinged endpaper utilizes cloth strips which are stripped around the first/last signatures and endpapers.[7] Whipstitched signature consists of one half of a signature sewn together. These various spine lining constructions and endpaper constructions are described in detail in Chapter 2.

The purpose of this study about Smyth-sewn Bible binding techniques was to:

(1) analyze a tubular liner construction and discover its aspects of durability performance when compared with the same aspects of a loose back construction.

(2) analyze the two most common endpaper reinforcing techniques of Bible bindings, whipstitched signature and hinged endpaper, to discover their characteristics in regard to durability with four-page tipped-on endpaper.

The information gained in regard to joint constructions may aid to optimize binding methods and determine production standards and/or recommendations for improvement.

The next chapter will consider the theoretical basis of this study.

FOOTNOTES FOR CHAPTER 1

1. Chandler B. Grannis, "Book Sales Statistics: Highlights from AAP Survey, 1987 and 1988" Library and Book Trade Almanac 34th Edition 1989-90 (New York: R.R. Bowker Company, 1989), pp.435-437.

2. Werner Rebsamen, "Joint Adhesion," The New Library Scene (August 1983), p.7.

3. Werner Rebsamen, Planning and Finishing (Rochester: Rochester Institute of Technology), Glossary of Terms: Useful to Buyers of Text Papers.

4. Werner Rebsamen, Planning and Finishing (Rochester: Rochester Institute of Technology), Binding and Shipping Terminology p.17.

5. Matt T. Roberts and Don Etherington, Bookbinding And The Conservation Of Books (Washington: Library of Congress, 1982), p.183.

6. Werner Rebsamen, "Endpapers — A Fundamental Part of Bookbinding," The Library Scene (March 1979), p.18.

7. Ibid.

Chapter 2

THEORETICAL BASIS

The following discussion is concerned with the spine lining and endpaper reinforcement, which are two most important factors of joint construction between the cover and the bookblock of Smyth-sewn Bible bindings.

Spine Lining: Loose Back And Tubular Liner Constructions

Spine lining is the process of reinforcing the spine of a sewn bookblock. After gluing-off, trimming and rounding, the bookblocks are lined on the spine with gauze and kraft paper. The purpose of lining the spine is to support it and to impart a certain degree of rigidity, while still maintaining the necessary flexibility for proper opening.[1] Loose back and tubular lining are techniques used to reinforce adhesion of the bookblock to the cover.

Loose back binding is a popular style of binding in which the spine binding material is not glued to the binding edge of the text sheets [2] (See Figure 1). It is a binding style having a space between the spine of the book block and the spine of the cover, resulting from the covering material being attached at the joints and not being glued to the spine of the book block.

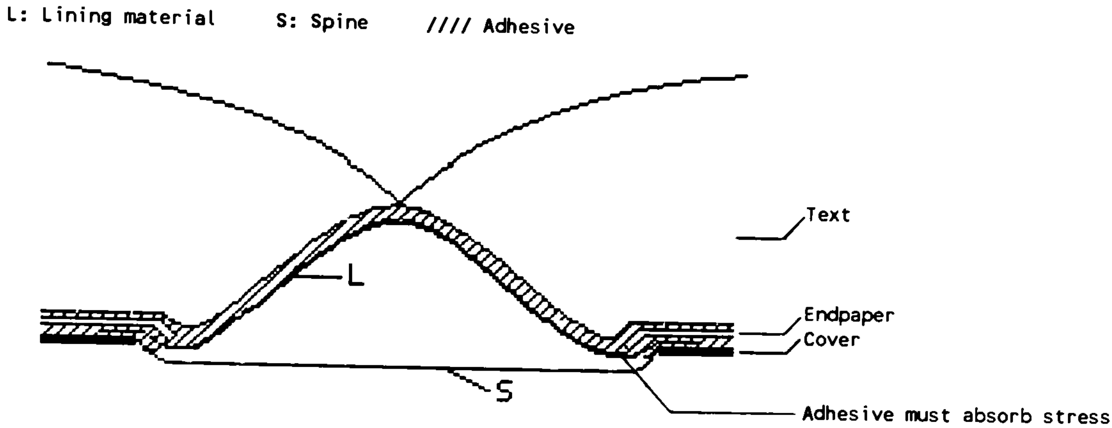

FIGURE 1 - SPINE LINING CONSTRUCTION:
Loose Back

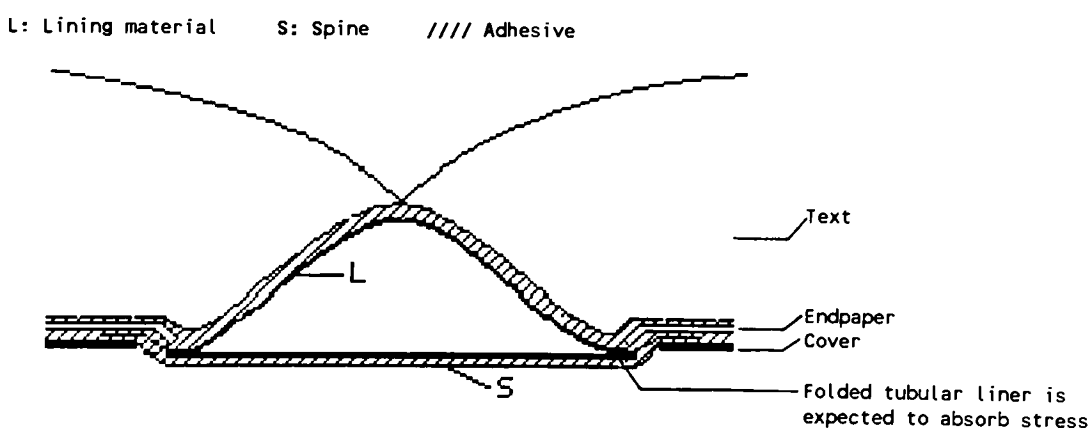

FIGURE 2 - SPINE LINING CONSTRUCTION:
Tubular Liner

Tubular liner consists of a simple flat tube which is then glued to the spine of the book block, and to the in-lay of the covers, leaving a hollow opening between the bookblock and the case [3] (See Figure 2). Tubular liners are pieces of strong paper or cloth and a hollow construction. These tubular liners are then mounted tightly to the spines. When casing-in, adhesive is applied over the entire backbone. Thereafter, the bookblock is mounted squarely and tightly into the case. After a drying period, the joints and endpapers are pasted-off and the bookblocks are pressed and built-in in regular fashion.[4]

Functions Of Endpaper

Endpapers are the units of two or more leaves placed in the front and back of a book between its covers and text block. Their function is to link the book to its cover, to hide some constructional features of the binding, and to protect the first few pages of the text. The endpapers perform the crucial function of holding the text block in its covers, or case. In addition, the board papers and fly leaves have long provided a medium for decoration.[5]

Endpaper Reinforcement

Four-page endpapers are the most widely used endpapers for casebound books and similar styles. This method is acceptable for use with books that will receive little wear. **Four-page tipped-on** endpapers are usually tipped to the first and last part of a text block only by a thin line of adhesive (See Figure 3). There is no reinforcement in the joint area, so constant opening and closing will eventually cause the binding to split.[6]

The whipstitched signature and the hinged endpaper reinforcements are two major endpaper reinforcement techniques for Bible bindings. The hinged endpaper is used for books and bindings designated for heavy use. Books sewn through the bindfold, that is Smyth sewn, have a four page endpaper tipped to the first and last pages of a book. The cloth strips approximately one inch wide are then stripped around the first and last signatures in order to reduce stress when opening and closing the book (See Figure 4). This technique allows the cloth reinforcement to be sewn to the bookblock, and thus making the cotton cloth invisible.[7] It also prevents the possibility of the sheet tearing away from the one to which it is attached.

Whipstitching is a process of sewing single sheets together (See Figure 5). The number of sheets sewn depends

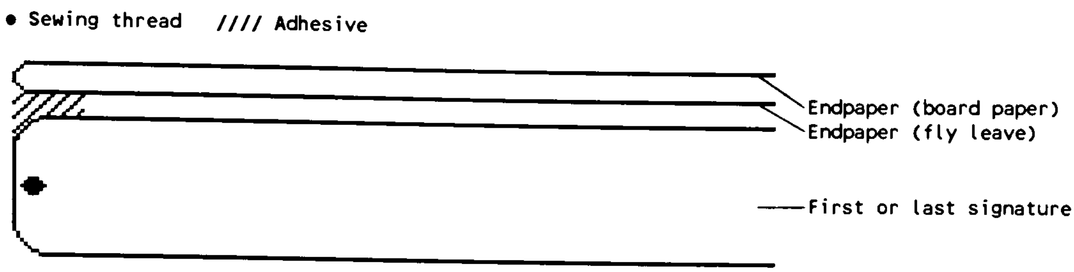

FIGURE 3 - ENDPAPER CONSTRUCTION:
Four-page Tipped-on Endpaper

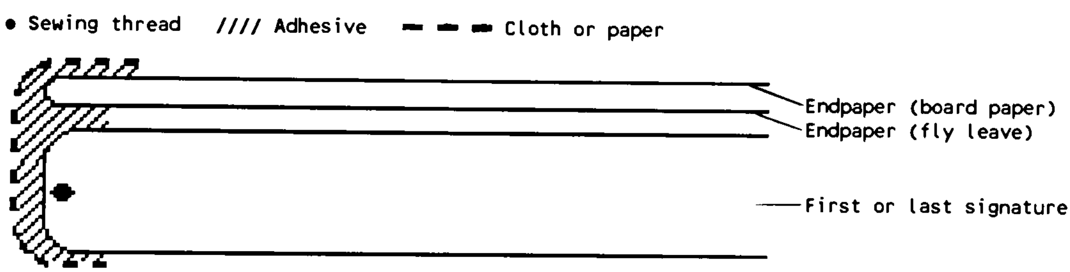

FIGURE 4 - ENDPAPER REINFORCEMENT:
Hinged Endpaper

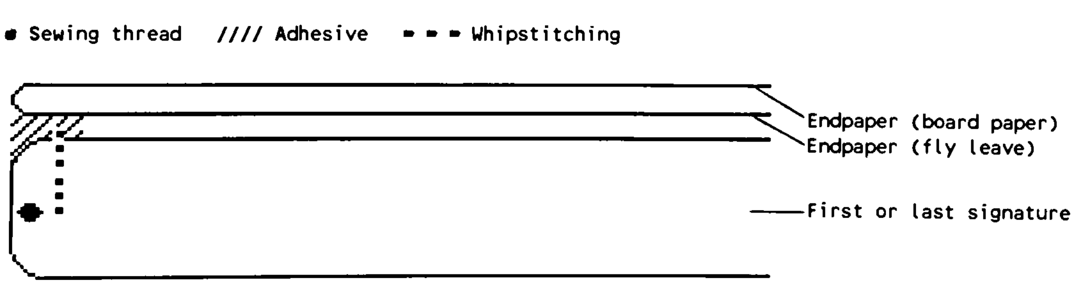

FIGURE 5 - ENDPAPER REINFORCEMENT:
Whipstitched Signature

on the thickness of a signature i.e. 32 or 64 pages. Only one half of a signature is sewn. The reason for whipstitching is that eight or sixteen leaves of paper sewn together provide more strength than a single sheet of thin Bible paper.

FOOTNOTES FOR CHAPTER 2

1. Matt T. Roberts and Don Etherington, Bookbinding And The Conservation Of Books (Washington: Library of Congress, 1982), p.245.

2. Werner Rebsamen, Planning and Finishing (Rochester: Rochester Institute of Technology), Binding and Shipping Terminology p.17.

3. Matt T. Roberts and Don Etherington, Bookbinding And The Conservation Of Books (Washington: Library of Congress, 1982), p.183.

4. Werner Rebsamen, "Joint Adhesion," The New Library Scene (August 1983), p.16.

5. Matt T. Roberts and Don Etherington, Bookbinding And The Conservation Of Books (Washington: Library of Congress, 1982), pp.89-92.

6. Werner Rebsamen, "Endpapers — A Fundamental Part of Bookbinding," The Library Scene (March 1979), p.18.

7. Ibid., pp.18-19.

Chapter 3

LITERATURE REVIEW

The literature investigated regarding this study of joint strength and durability between the cover and the bookblock of Smyth-sewn Bible bindings is organized into three parts: spine lining, endpaper reinforcement, and testing methods.

Spine Lining And Endpaper Reinforcement

The purpose of lining the spine is to support it and to impart a certain degree of rigidity, while still maintaining the necessary flexibility for proper opening. In these aspects, a tubular liner could be the most desirable construction among various spine lining constructions. Werner Rebsamen, Technical Director to LBI and Professor at Rochester Institute of Technology, expresses the advantages of tubular liner as follows:

> "Tubular liners allow the books to flex freely, yet give that extra strength to the joints where it is needed most. Tubular liners are the best choice in the construction of durable casebindings, since they combine that extra strength with good openability."[1]

Properly constructed endpapers are essential for the durability of bound hardcover books. Rebsamen stresses their importance: "It is most important that the endpaper

construction chosen has good dimensional stability and offers flexing characteristics."[2]

In a well-bound book there should be no stress on the first and last leaves. The cover should open and close in an unrestricted fashion. However, not all endpaper constructions offer these features. In a four-page tipped-on endpaper construction, tipping will cause stress on the first and last leaves, certainly not a good choice when the text block is adhesive bound or contains weak paper.[3] In a hinged endpaper construction, the extra stiffness in the joint area helps the binding hold its shape when rounded and backed. However, Rebsamen says that it creates a pull on the first leaf of the book and makes the cover harder to open.[4]

Testing Methods

Rebsamen states some important points in preparing for testing books:

> "In comparison performance testing, it is most important that the books be of equal dimension, weight and paper. The ideal testing book should weigh about three pounds and be approximately 6 x 9 inches in size."[5]

Several methods for testing joint strength have been developed in order to study the critical aspects of good adhesion.[6] Two common methods are the hinge-pull test and the tumble test such as the UBT (Universal Book Tester) test.

The hinge-pull test can be performed on the Robbins & Bendror Polytester, which is a low cost, multipurpose testing device. The Polytester is used to measure the tensile strengths such as page-pull, page-flex, cover flex, joint adhesion, spine pull and corner pull.[7]

The strength of a book in use can be regarded as the important criterion of its strength.[8] With the UBT, researchers have found that approximately 90 percent of the failures which occur out in the field can be duplicated in about the same proportions. The remaining 10 percent gap can further be closed if the UBT is combined with heat-aging.[9] The Universal Tester, developed by the W.J. Barrow research Laboratory through sponsorship of the Library Technology Project of ALA, consists of a rectangular chamber, rotating at about 23 revolutions per minute in a plane inclined at 20 degrees to the horizontal. Rebsamen explains how it works:

> "The sides of the bottom of the test chambers were rounded to a 1-1/2 inch radius, to concentrate the stresses along the shoulder of the spine. In order to test for abrasion, all chambers are lined with a stainless steel fabric to provide abrasion."[10]

According to Jack Bendror, the UBT tester produces the following results:[11]

1. Abrasion of the shoulder of the spine or external hinge.
2. Impact and abrasion on the head and tail caps.
3. Light abrasion of the cover.

4. Limited flexing of the external and internal hinges.
5. Breaking and tearing of the internal hinge.
6. Occasional failure of the sewing, loosing of signatures and splitting of the spine.

In addition to the UBT tumble test and Hinge-pull test, the Page-pull test is performed by the Moffett tester to give some useful information about tensile pull resistance of text leaves of the first and last signatures, which could be affected by different joint constructions. However, it is important to bear in mind that the page-pull test individually do not measure the binding strength.[12]

FOOTNOTES FOR CHAPTER 3

1. Werner Rebsamen, "Joint Adhesion," The New Library Scene (August 1983), p.16.

2. Werner Rebsamen, "Endpapers — A Fundamental Part of Bookbinding," The Library Scene (March 1979), p.19.

3. Werner Rebsamen, "Endpaper Construction for Recasing," The New Library Scene (June 1985), p.17.

4. Werner Rebsamen, "Endpapers — A Fundamental Part of Bookbinding," The Library Scene (March 1979), p.19.

5. Werner Rebsamen, "Bookbinding Testing Laboratory Evaluates Machinery, Materials, Techniques, Book Production Industry & Magazine Production (May 1977), p.66.

6. Werner Rebsamen, "Joint Adhesion," The New Library Scene (August 1983), p.18.

7. Werner Rebsamen, "Bookbinding Testing Laboratory Evaluates Machinery, Materials, Techniques, Book Production Industry & Magazine Production (May 1977), p.64.

8. Seija Korhonen, "Factors affecting the strength of a book," Advances in Printing Science and Technology - Proceedings of the 14th International Conference of Printing Research Institute Marbella, Spain (Finland: Graphic Arts Research Institute, June 1977), p.368.

9. Werner Rebsamen, "Performance Testing With the Universal Book Tester," The New Library Scene (October 1987), p.13.

10. Ibid., p.14.

11. Jack Bendror, Technology and Testing of Library Bound Books (Rochester, NY: Graphic Arts Research Center, RIT, 1976), p.8.

12. Ibid., p.6.

Chapter 4

HYPOTHESES AND RATIONALE

Statement Of The Problem

The principal judgement criterion to be used in this study is the durability of bindings. Durability means the ability of a bound volume to remain in its case without deterioration, while being subjected to stresses which it may receive in actual use.

Tubular liners are assumed to increase binding durability as well as maintaining good openability. Endpaper reinforcements such as whipstitched signature and hinged endpaper have been assumed to increase binding durability.

A series of tests were designed to answer the following specific questions:

1. Are there any significant differences in the Smyth-sewn hardcover Bible binding strength between the different spine lining constructions of loose back and tubular liner?
2. Are there any significant differences in the strength of Smyth-sewn hardcover Bible bindings between the different endpaper constructions of four-page tipped-on endpaper, whipstitched signature, and hinged endpaper?

Hypotheses

This study will examine the following hypotheses.

1a: There will be no significant differences at a 95% confidence level in the Smyth-sewn hardcover Bible binding strength between the loose back and the tubular liner constructions as measured by the UBT tumble test.

1b: There will be no significant differences at a 95% confidence level in the strength of Smyth-sewn hardcover Bible bindings:

(1) between the four-page tipped-on endpaper and the hinged endpaper constructions,

(2) between the four-page tipped-on endpaper and the whipstitched signature constructions,

(3) between the hinged endpaper and the whipstitched signature constructions,

as measured by the UBT tumble test.

2a: There will be no significant differences at a 95% confidence level in the Smyth-sewn hardcover Bible binding strength between the loose back and the tubular liner constructions as measured by the Hinge-pull test.

2b: There will be no significant differences at a 95% confidence level in the strength of Smyth-sewn hardcover Bible bindings:

(1) between the four-page tipped-on endpaper and the hinged endpaper constructions,

(2) between the four-page tipped-on endpaper and the whipstitched signature constructions,

(3) between the hinged endpaper and the whipstitched signature constructions,

as measured by the Hinge-pull test.

3a: There will be no significant differences at a 95% confidence level in the Page-pull test results for Smyth-sewn hardcover Bible bindings constructed in loose back, versus those constructed with tubular liner.

3b: There will be no significant differences at a 95% confidence level in the Page-pull test results for Smyth-sewn hardcover Bible bindings constructed:

(1) with four-page tipped-on endpaper versus with hinged endpaper,

(2) with four-page tipped-on endpaper versus with whipstitched signature,

(3) with hinged endpaper versus with whipstitched signature.

Chapter 5

RESEARCH DESIGN AND METHODOLOGY

Experimental Design

This experiment was constructed as a 2 x 3 factorial design. The first factor to be examined was spine lining construction. The two levels of spine lining were loose back and tubular liner constructions. The second factor to be examined was endpaper reinforcement construction. The three levels of endpaper reinforcement were four-page tipped-on endpaper, hinged endpaper, and whipstitched signature.

This design yielded six (2 x 3) crossed book treatments (see Table 1). 13 replicates were prepared for each of six book treatments, for a total of 78 test volumes (6 crossed treatments x 13 replicates = 78 test volumes).

SPINE LINING CONSTRUCTION	ENDPAPER REINFORCEMENT CONSTRUCTION	TESTING VOLUMES
Loose back	Four-page tipped-on endpaper	13
	Hinged endpaper	13
	Whipstitched signature	13
Tubular liner	Four-page tipped-on endpaper	13
	Hinged endpaper	13
	Whipstitched signature	13
	TOTAL:	78

Table 1 - BOOK TYPE PREPARATIONS

Book Preparation

The materials and procedures utilized to produce the test volumes for this study were chosen to follow common industry production standards for Smyth-sewn hardcover Bibles. Also, those Smyth-sewn hardcover Bibles to be tested were produced and provided by the Pochinchai Printing Co., Ltd., which is one of the major commercial printers and binders in Korea.

The trim sizes of the volumes tested were 6 by 9 inches by 1 5/8 inches thick. All bound volumes weighed three pounds. The bookblocks were rounded and backed. The same 24 lb. basis Bible paper was used for all volumes. The tubular liners were made up of strong kraft paper. 120 lb. endpaper stock from the same production lot was used. The paper grain was parallel to the spine of the book. One inch wide muslin strips were used to construct the hinged endpapers.

Book Testing

To measure joint strength and durability, three specific tests were selected: UBT tumble test, Hinge-pull Test, and Page-pull test. 30 books were subjected to each of UBT test and Hinge-pull test. 18 books were subjected to Page-pull test, (see Appendix A for book preparations for each test).

UBT Tumble Test: A book to be tested was placed in the bottom of the chamber. The spine of the book was perpendicular to the squared ends of the chamber. As the chamber rotated, the book slid in a regulated manner; receiving impact stresses on the bottom, along with abrasion of the edges and shoulder, and some flexing of the hinges.[1] The duration for the UBT test to produce the best result was 60 minutes (about 1380 revolutions).[2] The words of "the duration for the best result" meant the appropriate testing time which could show any existing variation in strengths between different binding constructions. In utilizing the UBT test, the qualitative data on the durability of bound volumes were produced. Therefore, in order to transform the qualitative data into the quantitative data, this study utilized the following five point rating index developed by Chaback.[3] Each volume tested was inspected as to the performance, then a numerical rating was assigned to that.

1) Inferior: Split endpaper, severely loose joints, book block hanging loose between cover boards, endpaper separation from book block.
2) Poor: Partially split endpaper, loose joints, endpaper coming loose from boards but not more than a quarter of an inch.

3) Fair: Slight split or other damages to endpaper construction, loose joint, endpaper remained adhered to boards, no separation from book block, internal split endpaper.
4) Good: Slightly loose joints, endpapers adhered well to boards, no separation from book block.
5) Superior: no damages, no loose joints, good adhesion throughout.

Hinge-Pull Test By Polytester: The bound volumes were first split on the spine of the case so that the strength of case materials did not affect test results. The object was to test the strength of the cover joint only. The book was laid face down on the table and one cover was inserted through the slot in the book clamp; the clamp was then lowered and tightened against the book. The page clamp gripped the cover. Pressure was applied with the hand lever. The tensile force required to pull the cover from the binding was recorded on the digital meter in pounds.

Page-Pull Test By Moffett Tester: The second text sheets to the fly endpapers were pulled from each book. The book was placed flat on the base place, and the page to be tested was inserted upward through the wedge. Then the

captivating rod was slowly turned until the slot was facing the operator. The end of the page was inserted into the slot and the rod was turned until the book was drawn upward and the apex was resting firmly against the bottom of the front and back wedges. Then the red indicator in the test gauge was set to zero. By activating the valve, the pneumatic pressure force continued to build until the page was pulled out. The pounds of Pull test were recorded by the red indicator on the test gauge. The tensile force value can be expressed in pounds per linear inch if compared books with different spine lengths.

Delimitations And Limitations

This study was limited to testing Smyth-sewn hardcover Bibles using 24 lb. basis Bible paper and 120 lb. basis endpaper stock. The tubular liners were made up of strong kraft paper, and muslin strips were used to construct the hinged endpapers. This study did not evaluate any binding materials. The deviating factors were only the spine lining construction and the endpaper construction used. The test results were to be based on only the different binding structures. However, they could be affected by the material failures which were not taken into account in the assessment of binding deterioration in this case.

Another limitation to this study was its reliability due to the small sample sizes. The fact that only five replicates per treatment were used for UBT test and Hinge-pull test and three replicates per treatment were used for Page-pull test caused some concern. The extraneous variation in one test sample would skew the readings for the entire treatment. However, the small sample size was unavoidable due to limited resources available to this research. To avert this kind of variation, all testing samples were carefully inspected to see if they had any kind of defect, before they were accepted for a given test.

Statistical Analysis

With the statistics package SAS (Statistical Analysis System) on the RIT VAX computer system, a two-way analysis of variance (ANOVA) was performed to test each hypothesis. The ANOVA is used to assign a portion of the total variability within the data set to the individual factors under consideration by comparing the means for each treatment. If the difference between the means is larger than the calculated 'F' ratio, then the difference is deemed to be the result of something other than a naturally occurring variation. In this case the null hypothesis is rejected.[4] For this study an alpha level of 0.05 was used,

which meant that a conclusion drawn had a 95 percent probability of being correct. The ANOVA was performed again at an alpha level of 0.01 for comparison.

The ANOVA does not identify which factors are responsible for the rejection of the null hypothesis. If the null hypothesis had been rejected, to identify which treatments were significantly different from each other, the Duncan Multiple Range Test was performed with the VAX statistics program SAS.

The means for each treatment were calculated and plotted using a Lotus 1-2-3 spreadsheet on a IBM PC.

The tables of the test data and the ANOVA with Duncan Multiple-Range Test summaries are included in the Appendix section.

FOOTNOTES FOR CHAPTER 5

1. Werner Rebsamen, "Performance Testing With the Universal Book Tester," The New Library Scene (October 1987), p.15.

2. Geoffrey T. Hyatt, Factors Affecting the Strength and Openability of Tight Backed, Adhesive Bound, Hardcover Volumes (Rochester, NY: Master's Thesis, RIT, August 1988), p.29.

3. Claudia E. Chaback, A Performance Comparison Between A Wide-Hinged Endpaper Construction and The Library Binding Institute Standard Endpaper Construction (Rochester, NY: Master's Thesis, RIT, May 1987), p.35.

4. David Anderson et al, Statistics: Concepts and Applications (St. Paul, MN: West Publishing Company, 1986), p.495.

Chapter 6

RESULTS AND ANALYSIS OF DATA

UBT Tumble Test Analysis

According to the ANOVA analysis (see Table 8) and the Duncan Multiple-Range test (see Table 9) of UBT tumble test results, all of the following hypotheses were rejected:

1a: There will be no significant differences at a 95% confidence level in the Smyth-sewn hardcover Bible binding strength between the loose back and the tubular liner constructions as measured by the UBT tumble test.

1b: There will be no significant differences at a 95% confidence level in the strength of Smyth-sewn hardcover Bible bindings:

(1) between the four-page tipped-on endpaper and the hinged endpaper constructions,

(2) between the four-page tipped-on endpaper and the whipstitched signature constructions,

(3) between the hinged endpaper and the whipstitched signature constructions,

as measured by the UBT tumble test.

Based on the ANOVA analysis of UBT tumble test results at the 95% confidence level, the calculated F value for

spine lining constructions was 30.32 while the critical F value was 4.02. Since the calculated F value exceeded the critical F value, there was evidence of significant differences among the spine lining constructions. Therefore, the Hypothesis 1a was rejected. The Duncan Multiple-Range Test for spine lining constructions confirmed the rejection of Hypothesis 1a by grouping tubular liner construction and loose back construction into the different groups, which meant they were significantly different in durability. Also, it showed that the mean durability rating for books bound using tubular liner construction was 3.8333 whereas the mean for books bound using loose back construction was 2.4667. Therefore, books bound using tubular liner construction appeared to be more durable than books bound using loose back construction.

From the ANOVA analysis of UBT tumble test results, we got the calculated F value of 49.35 and the critical F value of 3.17 for endpaper constructions. Since the F statistics for endpaper constructions was significant, there were significant differences in durability related to the endpaper constructions. According to the Duncan Multiple-Range Test for endpaper constructions, neither of four-page tipped-on endpaper, hinged endpaper, and whipstitched signature constructions had same letter in Duncan grouping.

That revealed all three endpaper constructions were significantly different from each other in durability. Thus, the Hypotheses 1b-(1), 1b-(2), and 1b-(3) were rejected. The Duncan Multiple-Range Test for endpaper constructions gave us the following mean values of durability rating for books utilizing each endpaper constructions: 4.75 for hinged endpaper reinforcement construction, 2.95 for four-page tipped-on endpaper construction, and 1.75 for whipstitched reinforcement construction. Thus, books bound with hinged endpaper appeared to be much more superior in durability than others, and book bound with four-page tipped-on endpaper were next-superior. It was quite interesting point that books bound with whipstitched signature yielded the inferior results in UBT tumble test as compared to books bound with four-page tipped-on endpaper which had no endpaper reinforcement.

The ANOVA analysis of UBT tumble test results showed that the significant interactions between spine lining constructions and endpaper constructions were present. An interaction is an additional effect due to the particular combination of the two levels. Therefore, the degree of superiority in durability varied form construction to construction. Figure 6 shows the interaction plots of UBT tumble test mean values. Geometrically, interactions are

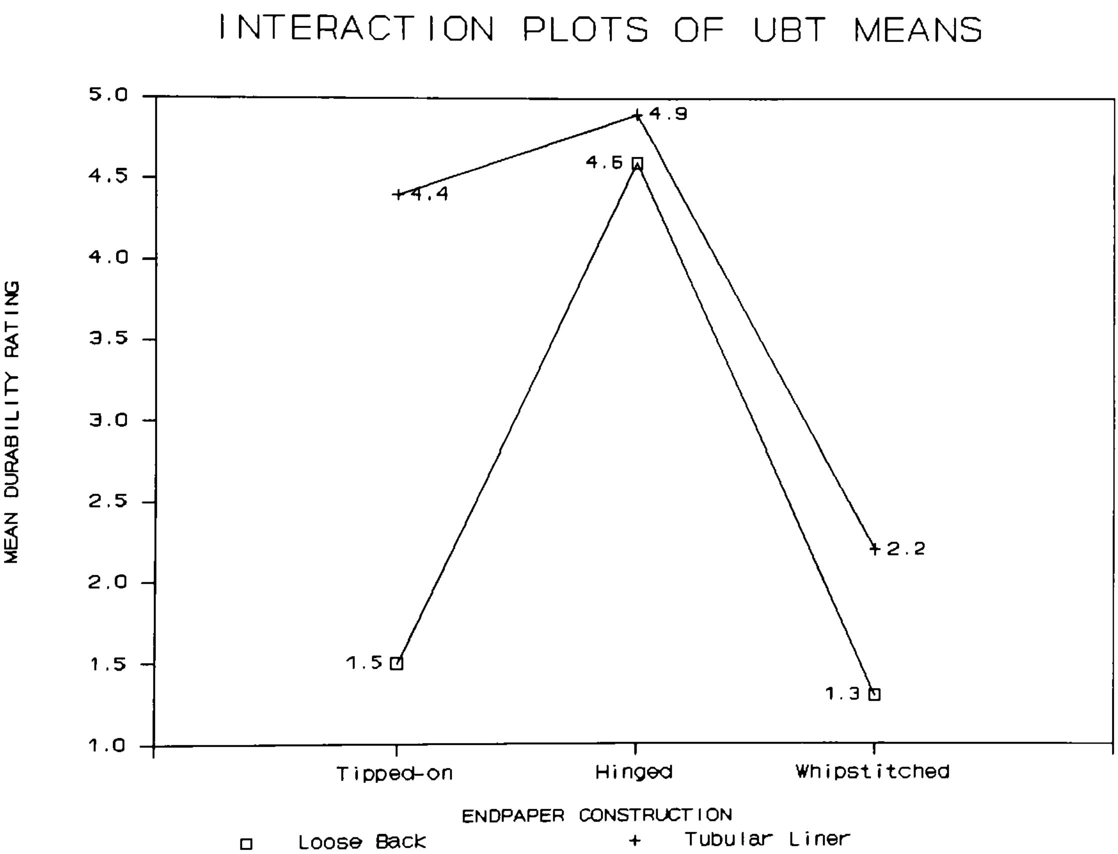

FIGURE 6 - INTERACTION PLOTS OF UBT MEANS

indicated by the deviations from parallelism. As indicated on the graph, books bound using tubular liner seemed to be superior in durability to those bound in loose back construction regardless of the various endpaper constructions. However, durability of book with four-page tipped-on endpaper was enhanced most dramatically with tubular liner. Books bound with four-page tipped-on endpaper and tubular liner showed the almost same high mean durability rating (4.4) as books bound with hinged endpaper in loose back (4.6). In the case of books bound with hinged endpaper, the mean durability rating went up to 4.9 with tubular liner form 4.6 with loose back, which was quite a small enhancement. This was because books bound with hinged endpaper in loose back had already showed excellent degree of durability, especially as compared to those bound with four-page tipped-on endpaper or whipstitched signature in loose back.

Polytester Hinge-pull Test Analysis

Based on the ANOVA analysis (see Table 10) and the Duncan Multiple-Range test (see Table 11) of Hinge-pull test results, the following hypothesis was accepted:

2a: There will be no significant differences at a 95% confidence level in the Smyth-sewn hardcover Bible

binding strength between the loose back and the tubular liner constructions as measured by the Hinge-pull test.

Also, the statistical analysis of the ANOVA with optional Duncan Multiple-Range Test indicated that all of the following hypotheses should be rejected:

2b: There will be no significant differences at a 95% confidence level in the strength of Smyth-sewn hardcover Bible bindings:

(1) between the four-page tipped-on endpaper and the hinged endpaper constructions,

(2) between the four-page tipped-on endpaper and the whipstitched signature constructions,

(3) between the hinged endpaper and the whipstitched signature constructions,

as measured by the Hinge-pull test.

According to the ANOVA analysis of Hinge-pull test results at the 95% confidence level, the calculated F value for spine lining constructions was 1.57 while the critical F value was 4.02. Since the calculated F value did not exceed the critical F value, there was no evidence of significant differences due to spine lining constructions. Therefore, the Hypothesis 2a was accepted. In accepting this

hypothesis, the probability of a Type Two error was 21.5%. The Duncan Multiple-Range Test for spine lining constructions supported the acceptance of Hypothesis 2a by grouping tubular liner construction and loose back construction into the same group, which meant they were not significantly different in hinge strength. It showed that the mean load for books bound in tubular liner construction was 303.833 lbs. and the mean load for books bound in loose back construction was 315.433 lbs., whereas the critical range was 18.5514. Therefore, books bound using both spine lining constructions could be considered equal in hinge strength.

From the ANOVA analysis of Hinge-pull test results, we got the calculated F value of 196.90 and the critical F value of 3.17 for endpaper constructions. Since the F statistics for endpaper constructions was significant, there were significant differences in hinge strength related to the endpaper constructions. According to the Duncan Multiple-Range Test at the 0.05 level for endpaper constructions, neither of four-page tipped-on endpaper, hinged endpaper, and whipstitched signature had same letter in Duncan grouping. That revealed that all three endpaper constructions were significantly different from each other in hinge strength. Thus, the Hypotheses 2b-(1), 2b-(2), and

2b-(3) were rejected. The Duncan Multiple-Range Test for endpaper constructions gave us the following mean loads for each constructions: 438.65 lbs. for hinged endpaper reinforcement construction, 257.25 lbs. for four-page tipped-on endpaper construction, and 233 lbs. for whipstitched reinforcement construction. Thus, books bound with hinged endpaper appeared to be most superior in hinge strength, and books bound with four-page tipped-on endpaper was next-superior. This indicated that books utilizing the hinged endpaper required the greatest force to be separated from the hinge of the bookblock. Same as in the statistical analysis of UBT tumble test results, the books bound with whipstitched signature yielded inferior results in the Hinge-pull test as compared to those bound with four-page tipped-on endpaper which had no endpaper reinforcement. However, it was observed that they belonged to the same Duncan grouping at the alpha level of 0.01, which meant they were not significantly different.

The ANOVA analysis of Hinge-pull test results did not show any significant interactions between spine lining constructions and endpaper constructions. Therefore, the degree of superiority in hinge strength varied only by endpaper constructions. Figure 7 shows the interaction plots of Hinge-pull test mean values, which were rather different

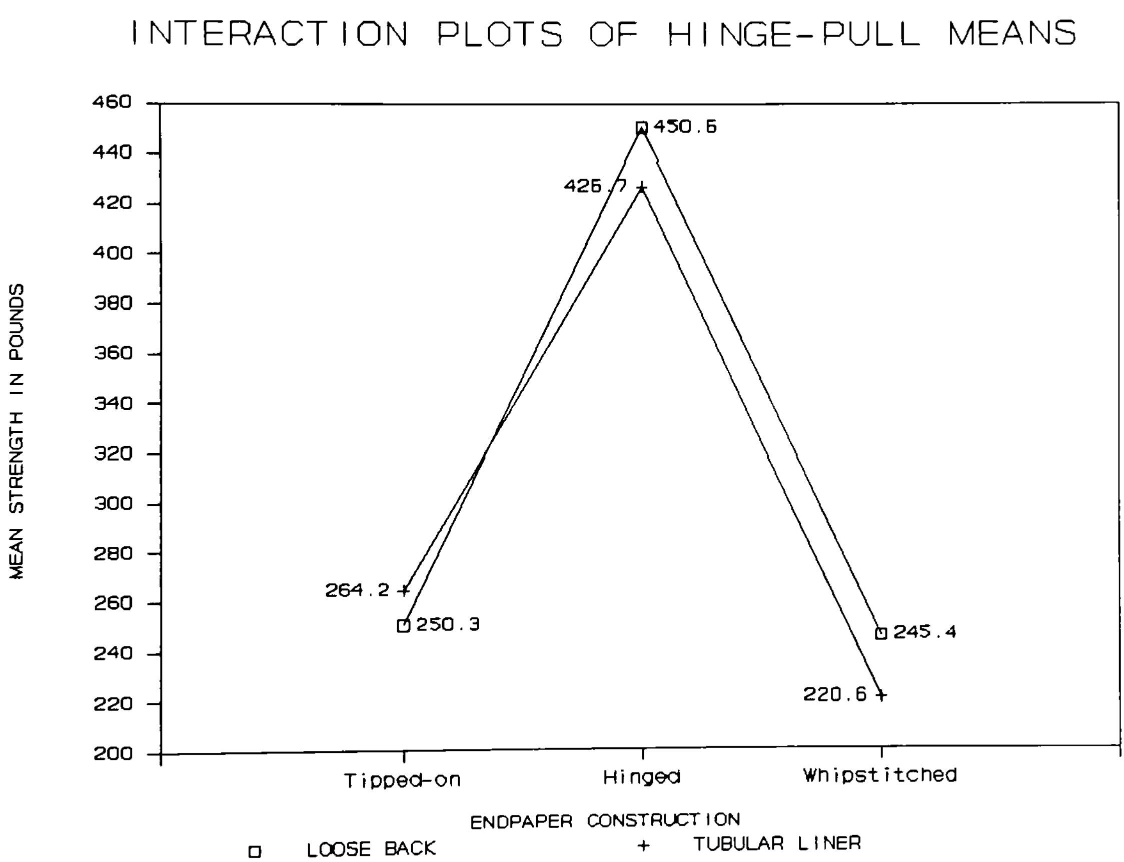

FIGURE 7 - INTERACTION PLOTS OF HINGE-PULL MEANS

in shapes from the plots of UBT tumble test means. The graphs for tubular liner construction and loose back construction ran almost parallel, and there did not appear to be any great difference in hinge strengths between books bound using those two spine lining constructions. Among the three different endpaper constructions, the books utilizing hinged endpaper construction showed much superior hinge strength to others regardless of spine lining construction types.

Moffett Page-pull Test Analysis

Based on the ANOVA analysis (see Table 12) and the Duncan Multiple-Range test (see Table 13) of Page-pull test results, the following hypotheses were accepted:

3a: There will be no significant differences at a 95% confidence level in the Page-pull test results for Smyth-sewn hardcover Bible bindings constructed in loose back, versus those constructed with tubular liner.

3b: There will be no significant differences at a 95% confidence level in the Page-pull test results for Smyth-sewn hardcover Bible bindings constructed:

(1) with four-page tipped-on endpaper versus with hinged endpaper.

Also, the statistical analysis of the ANOVA with optional Duncan Multiple-Range Test indicated that the following hypotheses should be rejected:

3b: There will be no significant differences at a 95% confidence level in the Page-pull test results for Smyth-sewn hardcover Bible bindings constructed:

(2) with four-page tipped-on endpaper versus with whipstitched signature,

(3) with hinged endpaper versus with whipstitched signature.

According to the ANOVA analysis of Page-pull test results at the 95% confidence level, the calculated F value for spine lining constructions was 0.14 while the critical F value was 4.17. Since the calculated F value did not exceed the critical F value, there was no evidence of significant differences due to spine lining constructions. Therefore, the Hypothesis 3a was accepted. In accepting this hypothesis, the probability of a Type Two error was 71.4%. The Duncan Multiple-Range Test for spine lining constructions supported the acceptance of Hypothesis 3a by grouping tubular liner construction and loose back construction into the same group, which meant they were not significantly different in page-pull strength. It showed

that the mean load for books bound in tubular liner construction was 30.889 lbs. and the mean load for books bound in loose back construction was 30.500 lbs., whereas the critical range was 2.14739. Therefore, books bound with those two spine lining constructions could be considered equal in page-pull strength. This was the result that we expected, because spine lining constructions do not affect the binding structure and strength of text papers.

From the ANOVA analysis of Page-pull test results, we got the calculated F value of 242.68 and the critical F value of 3.32 for endpaper constructions. Since the F statistics for endpaper constructions was significant, there were significant differences in page-pull strength related to the endpaper constructions. According to the Duncan Multiple-Range Test at the 0.05 level for endpaper constructions, four-page tipped-on endpaper and hinged endpaper constructions belonged to the same group in Duncan grouping. That revealed that those two endpaper constructions were not significantly different from each other in page-pull strength. Thus, the Hypothesis 3b-(1) was accepted. Whipstitched signature construction appeared to be strongest and appeared by itself in Duncan grouping, meaning it was significantly different from other endpaper constructions. Thus, the Hypotheses 3b-(2) and 3b-(3) were

rejected. The Duncan Multiple-Range Test for endpaper constructions gave us the following mean loads for each constructions: 47.083 lbs. for whipstitched endpaper reinforcement construction, 22.500 lbs. for four-page tipped-on endpaper construction, and 22.500 lbs. for hinged reinforcement construction. This indicated that the books constructed with whipstitched endpaper required the greatest force to pull out a page from the first or last signature.

The ANOVA analysis of Page-pull test results did not show any significant interactions between spine lining constructions and endpaper constructions. Therefore, the degree of superiority in page-pull strength varied only by endpaper constructions. Figure 8 shows the interaction plots of Page-pull test mean values. The graphs for tubular liner construction and loose back construction showed almost parallelism, and there did not appear to be any significant difference in page-pull strengths between books bound using those two spine lining constructions. Among the three different endpaper constructions, the books constructed with whipstitched endpaper showed about twice superior page-pull strength as compared to those bound with other endpaper constructions regardless of spine lining construction types.

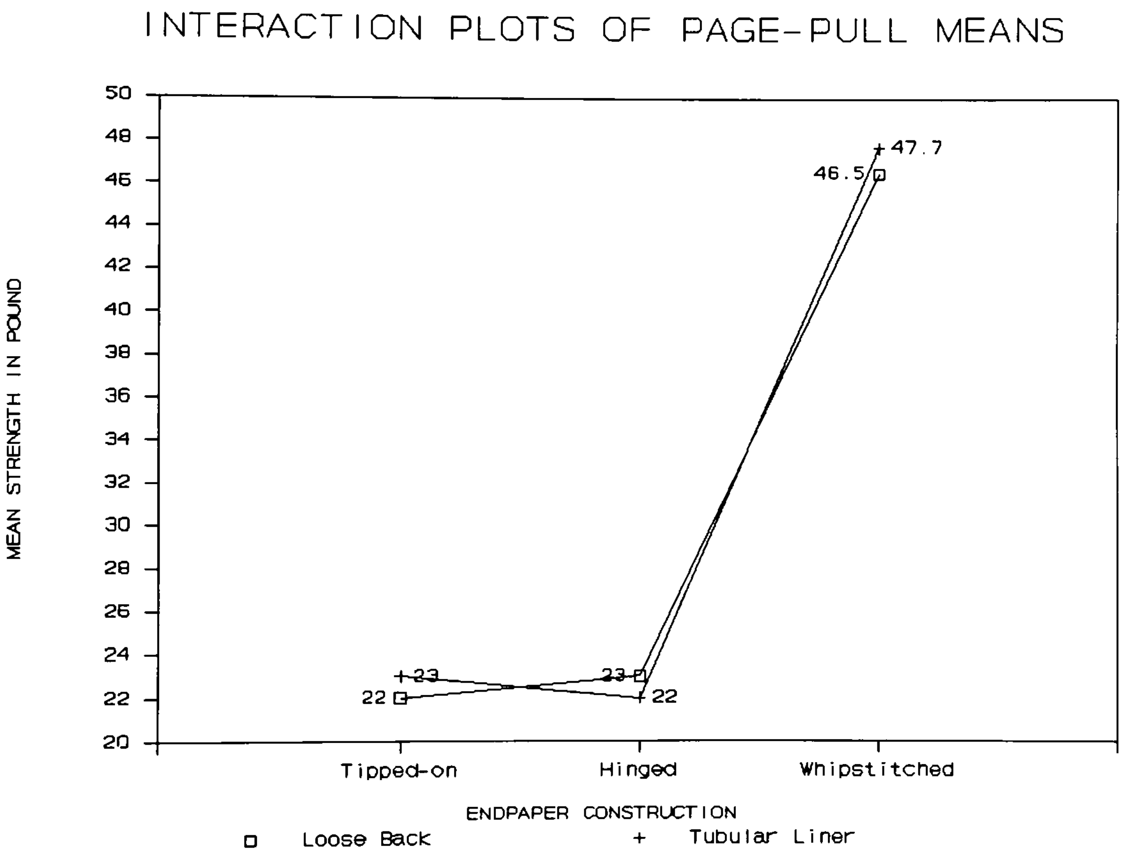

FIGURE 8 - INTERACTION PLOTS OF PAGE-PULL MEANS

Chapter 7

SUMMARY AND CONCLUSIONS

The objective of this study about Smyth-sewn Bible binding techniques was to:
(1) analyze a tubular liner construction and discover its aspects of durability performance when compared with the same aspects of a loose back construction,
(2) analyze the two most common endpaper reinforcing techniques of Bible bindings, whipstitched signature and hinged endpaper, to discover their characteristics in regard to durability with four-page tipped-on endpaper.

To achieve these objectives, 78 Bibles were tested utilizing UBT tumble test, Hinge-pull test, and Page-pull test. The results were analyzed by a two-way ANOVA with optional Duncan Multiple-Range Test at a 95% confidence level, and compared with the hypotheses concerning bookbinding strength and durability. Furthermore, graphical analyses were made by plotting treatment means for each test.

The following specific questions were asked to summarize and conclude the findings from testing the hypotheses by a two-way ANOVA with optional Duncan Multiple-Range Test and by graphical analysis of treatment means.

1. Are there any significant differences in the Smyth-sewn hardcover Bible binding strength between the different spine lining constructions of loose back and tubular liner? - Yes.

The UBT tumble test and Hinge-pull test, which are two common methods for testing joint strength, yielded contradictory results on this question.

The ANOVA analysis (Table 8) with Duncan Multiple-Range Test (Table 9) at a 95% confidence level and the graphical analysis (Figure 6) of UBT tumble test results indicated that there was evidence of extreme differences in durability among those two spine lining constructions, and that books constructed with tubular liner looked to be much more durable than books constructed in loose back.

On the contrary, the ANOVA analysis (Table 10) with Duncan Multiple-Range Test (Table 11) at a 95% confidence level and the graphical analysis (Figure 7) analyses of Hinge-pull test results revealed that there was no significant variability due to spine lining constructions.

This considerable discrepancy would result from the nature of the test methods and the nature of materials used. In the Hinge-pull test of books constructed with tubular liner, the tubular liner material was not cut off but split internally when a cover was pull out from bookblock. But in

the UBT tumble test, the tubular liner material was not split internally but cut off if the book had failed. It seemed that in each tests, the stresses and forces distressed the tubular liner materials in different ways to make them fail during testing. The Hinge-pull test is used to examine only the hinge strength. Also, the tubular liner material, in this case the strong kraft paper, seemed to have much weaker internal split strength than cut-off strength. Therefore, it would be better in Hinge-pull test if we had used tubular liner made with cloth, which did not seem to reveal any material failure before binding deterioration.

The UBT tumble test is considered to have shown and given the best correlation to the physical breakdown of books in actual use. Thus it would be reasonable to conclude that tubular liner constructions are assumed to increase binding durability as compared to loose back constructions.

2. Are there any significant differences in the strength of Smyth-sewn hardcover Bible bindings between the different endpaper constructions of four-page tipped-on endpaper, whipstitched signature, and hinged endpaper?
   - Yes.

The UBT tumble test and Hinge-pull test provided the same results on this question. The ANOVA analysis (Table 8) with Duncan Multiple-Range Test (Table 9) at a 95% confidence level and the graphical analysis (Figure 6) of UBT tumble test results indicated that there was evidence of significant differences in durability among those three endpaper constructions, and that books constructed with hinged endpaper reinforcement was much more durable than books constructed with four-page tipped-on endpaper and whipstitched signature. The most inferior endpaper construction in durability was whipstitched signature reinforcement construction. Whipstitching resulted in high page-pull values, but it created a bundle of stiff papers which, if tumbled, could cause stress onto other parts and subsequent failure.

The ANOVA analysis (Table 10) with Duncan Multiple-Range Test (Table 11) at a 95% confidence level and the graphical analysis (Figure 7) of Hinge-pull test results revealed the same results as those of UBT tumble test. However, for comparison, the Duncan Multiple-Range test at the alpha level of 0.01 of Hinge-pull test results showed that there were not significant differences in hinge strength between four-page tipped-on endpaper and whipstitched signature constructions.

The ANOVA analysis (Table 12) with Duncan Multiple-Range Test (Table 13) at a 95% confidence level and the graphical analysis (Figure 8) of Page-pull test results revealed that whipstitched signature construction was significantly different and stronger in page-pull strength as compared to four-page tipped-on endpaper and hinged endpaper constructions. However, books bound with whipstitched signature were proved to be most inferior or not superior to others in binding strength and overall durability in UBT tumble test and Hinge-pull test. This was a quite surprising finding, especially when endpaper reinforcements such as whipstitched signature have been assumed to increase binding durability. This could be explained by examining the hinge splitting points when books failed by UBT tumble test and Hinge-pull test. Those two tests utilized 60 books, which giving 40 results (20 books) of hinge split condition for each endpaper constructions. For the books constructed with four-page tipped-on endpaper and whipstitched signature, none of them failed at the first text page tipped-on to endpaper (fly leaves) although tipping would cause stress on that. If they had failed, it was only at the endpaper hinge. Therefore, it was obvious that reinforcing endpaper construction by whipstitching the half of the first and last signatures attached to endpaper

would not make any difference in binding durability as compared to four-page tipped-on endpaper construction which had no endpaper reinforcement. And whipstitching seemed to make the first and last signature areas relatively stiff, so that destructive forces and stresses became havoc with the poorly flexing hinges.

For the books constructed with hinged endpaper, if they had failed and had splitting during tests, the splitting points were endpaper hinge, between the first text page and the endpaper (fly leave), and between the first signature and the next signature. This indicated that stresses were evenly distributed to all hinge areas. A hinged endpaper reinforcement appeared to greatly aid in unrestricted movement of hinge area, and the hinging strip seemed to act as a reinforcement as the needle passes through the folded paper and the cloth strip.

Thus it is a conclusion that hinged endpaper reinforcement construction extremely enhances the binding strength and durability of books, and books bound with hinged endpaper seem to be more durable than books bound with four-page tipped-on endpaper or with whipstitched signature reinforcement. Books constructed with four-page tipped-on endpaper are more durable only a very little than those bound with whipstitched signature.

The ANOVA analysis (Table 8) of UBT tumble test results indicated that the significant interactions between spine lining constructions and endpaper constructions were present. Constructed with tubular liner instead of loose back, the durability of books constructed with four-page tipped-on endpaper was enhanced significantly as compared to those bound with hinged endpaper or whipstitched signature. The books which were bound with hinged endpaper reinforcement (for both of tubular liner and loose back spine constructions) and the books which were bound with four-page tipped-on endpaper and tubular liner showed a significant superiority in binding strength and durability to others.

In many cases, material failure occurred before binding deterioration. This was particularly noticeable with the spine lining materials and endpaper materials. This is a quite important point to consider because the strength and durability of a bound product depends very much on good joint adhesion, and the good joint adhesion seems to depend very much on strengths of spine lining and endpaper materials as well as endpaper constructions. Therefore, to get the appropriate binding durability for end use, it is important to choose the good binding materials having proper strength for a given binding method.

Chapter 8

RECOMMENDATIONS FOR FURTHER STUDY

Repeating this study could be one of the suggestions for further research. This present study could be refined as follows:

1. by using larger sample sizes for each treatments. The limited number of replications for each treatments were utilized, and that was one of the limitations in this study,
2. by using stronger or better defined endpaper and spine lining materials for the test books. In this study, it was noticed that test results could be affected by the material failures before binding deterioration. Therefore, using better defined materials would help to isolate the influence of specific material properties on the test results of binding strength and durability.

The second suggestion for further research would be combining one of the following factors with the present two factors of spine construction and endpaper construction:

1. different binding methods of Smyth-sewn and Adhesive,
2. different binding methods of hardcover, softcover and flexible cover structures.

This gives better informations of possible effects on book construction due to a certain binding factor or the particular combination of the binding factors.

The third recommendation for further study would be utilizing the openability test as well as durability tests, thus making it easy to produce books with optimal characteristics and desired binding strength.

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APPENDICES

APPENDIX A

BOOK PREPARATIONS FOR TESTS

Table 2

BOOK PREPARATION FOR THE UBT TUMBLE TEST

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
HINGED ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
WHIPSTITCHED ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
					TOTAL:	30

F = Front Endpaper Side
B = Back Endpaper Side

Table 3

BOOK PREPARATION FOR THE HINGE-PULL TEST

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
HINGED ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
WHIPSTITCHED ENDPAPER	1	1F	1B	1F	1B	10
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
	4	4F	4B	4F	4B	
	5	5F	5B	5F	5B	
					TOTAL:	30

F = Front Endpaper Side
B = Back Endpaper Side

Table 4

BOOK PREPARATION FOR THE PAGE-PULL TEST

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	1F	1B	1F	1B	6
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
HINGED ENDPAPER	1	1F	1B	1F	1B	6
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
WHIPSTITCHED ENDPAPER	1	1F	1B	1F	1B	6
	2	2F	2B	2F	2B	
	3	3F	3B	3F	3B	
					TOTAL:	18

F = Front Endpaper Side
B = Back Endpaper Side

APPENDIX B

TEST DATA TABLES

Table 5

UBT TEST DATA

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	2	2	4	5	10
	2	1	1	3	5	
	3	1	1	3	5	
	4	1	4	4	5	
	5	1	1	5	5	
	X	1.5		4.4		
HINGED ENDPAPER	1	5	5	5	5	10
	2	4	5	5	5	
	3	5	5	5	5	
	4	3	4	5	5	
	5	5	5	4	5	
	X	4.6		4.9		
WHIPSTITCHED ENDPAPER	1	2	3	5	3	10
	2	1	1	1	1	
	3	1	1	1	1	
	4	1	1	1	1	
	5	1	1	3	5	
	X	1.3		2.2		
					TOTAL:	30

TESTED AT 1,380 REVOLUTIONS OR ONE HOUR

5 = Superior: No damages, no loose joint, good adhesion to board throughout
4 = Good: Slightly loose joint, endpaper adhered well to board, no separation from book block
3 = Fair: Slight split or other damages to endpaper construction, loose joint, endpaper remained adhere to board, no separation from book block, internal split endpaper
2 Poor: Partially split endpaper, loose joint, endpaper coming loose from board but not more than one quarter of an inch
1 = Inferior: Split endpaper, severely loose joint, book block hanging loose between cover boards, endpaper separation form book block

Table 6

HINGE-PULL TEST DATA

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	234	212	286	230	10
	2	273	251	251	276	
	3	256	294	296	273	
	4	189	226	280	258	
	5	301	267	270	222	
	X	250.3		264.2		
HINGED ENDPAPER	1	453	407	441	367	10
	2	438	506	445	396	
	3	485	496	493	384	
	4	421	389	427	459	
	5	422	489	391	464	
	X	450.6		426.7		
WHIPSTITCHED ENDPAPER	1	247	208	188	256	10
	2	249	236	234	193	
	3	215	181	249	201	
	4	301	272	180	259	
	5	236	309	210	236	
	X	245.4		220.6		
					TOTAL:	30

MEASURED IN POUNDS

Table 7

PAGE-PULL TEST DATA

BINDING	sample	LOOSE BACK front	LOOSE BACK back	TUBULAR LINING front	TUBULAR LINING back	VOLUMES
FOUR-PAGE TIPPED-ON ENDPAPER	1	21	19	25	27	6
	2	19	22	18	19	
	3	25	26	26	23	
	X	22.0		23.0		
HINGED ENDPAPER	1	24	25	20	21	6
	2	23	25	21	22	
	3	22	19	25	23	
	X	23.0		22.0		
WHIPSTITCHED ENDPAPER	1	50	44	44	43	6
	2	41	44	48	50	
	3	49	51	52	49	
	X	46.5		47.7		
					TOTAL:	18

MEASURED IN POUNDS

THE SECOND TEXT SHEETS FROM ENDPAPER (FLY LEAVE) WERE PULLED TO TEST.

APPENDIX C

STATISTICAL TEST RESULTS SUMMARY

Table 8

ANOVA SUMMARY OF UBT TEST

SOURCE	DF	ANOVA SS	F VALUE	PR > F	CRITICAL VALUE Alpha = 0.05	CRITICAL VALUE Alpha = 0.01
Spine Lining	1	28.01666667	30.32	0.0001	4.02	7.12
Endpaper Reinforcement	2	91.20000000	49.35	0.0001	3.17	5.01
Spine Lining x Endpaper Reinforcement	2	18.53333333	10.03	0.00D2	3.17	5.01

Table 9

DUNCAN'S MULTIPLE RANGE TEST SUMMARY OF UBT TEST

DF=54 MSE=0.924074

			ALPHA 0.05		ALPHA 0.01	
LEVEL	MEAN	N	* DUNCAN GROUPING	CRITICAL RANGE	* DUNCAN GROUPING	CRITICAL RANGE
FACTOR: SPINE LINING						
Tubular lining	3.8333	30	A	0.497875	A	0.66288
Loose back	2.4667	30	B	———	B	———
FACTOR: ENDPAPER REINFORCEMENT						
Hinged endpaper	4.7500	20	A	0.60977	A	0.811859
Four-page tipped-on	2.9500	20	B	———	B	———
Whipstitched endpaper	1.7500	20	C	0.641136	C	0.84636

* Means with the same letter in Duncan groupings are not significantly different.

Critical range X/Y: X Critical range for span 2 ranked averages

Y Critical range for span 3 ranked averages

Table 10

ANOVA SUMMARY OF HINGE-PULL TEST

SOURCE	DF	ANOVA SS	F VALUE	PR > F	Alpha 0.05 CRITICAL VALUE	Alpha 0.01 CRITICAL VALUE
Spine Lining	1	2018.40000000	1.57	0.2151	4.02	7.12
Endpaper Reinforcement	2	505239.63333333	196.90	0.0001	3.17	5.D1
Spine Lining x Endpaper Reinforcement	2	4878.90D00000	1.90	0.1592	3.17	5.01

Table 11

DUNCAN'S MULTIPLE RANGE TEST SUMMARY OF HINGE-PULL TEST

DF=54 MSE=1282.98

LEVEL	MEAN	N	ALPHA 0.05 * DUNCAN GROUPING	ALPHA 0.05 CRITICAL RANGE	ALPHA 0.01 * DUNCAN GROUPING	ALPHA 0.01 CRITICAL RANGE
FACTOR: SPINE LINING						
Loose back	315.433	30	A	18.5514	A	24.6997
Tubular lining	303.833	30	A	———	A	———
FACTOR: ENDPAPER REINFORCEMENT						
Hinged endpaper	438.65	20	A	22.7208	A	30.2509
Four-page tipped-on	257.25	20	B	———	B	———
Whipstitched endpaper	233.00	20	C	23.8895	B	31.5364

* Means with the same letter in Duncan groupings are not significantly different.

Critical range X/Y: X Critical range for span 2 ranked averages

Y Critical range for span 3 ranked averages

Table 12

ANOVA SUMMARY OF PAGE-PULL TEST

SOURCE	DF	ANOVA SS	F VALUE	PR > F	CRITICAL VALUE Alpha 0.05	CRITICAL VALUE Alpha 0.01
Spine Lining	1	1.36111111	0.14	0.7142	4.17	7.56
Endpaper Reinforcement	2	4834.72222222	242.68	0.0001	3.32	5.39
Spine Lining x Endpaper Reinforcement	2	8.72222222	0.44	0.6495	3.32	5.39

Table 13

DUNCAN'S MULTIPLE RANGE TEST SUMMARY OF PAGE-PULL TEST

DF=30 MSE=9.96111

LEVEL	MEAN	N	ALPHA - 0.05 * OUNCAN GROUPING	ALPHA - 0.05 CRITICAL RANGE	ALPHA 0.01 * DUNCAN GROUPING	ALPHA 0.01 CRITICAL RANGE
FACTOR: SPINE LINING						
Tubular lining	30.889	18	A	2.14739	A	2.89481
Loose back	30.500	18	A	———	A	———
FACTOR: ENDPAPER REINFORCEMENT						
Whipstitched endpaper	47.083	12	A	2.63	A	3.54541
Four-page tipped-on	22.500	12	B	———	B	———
Hinged endpaper	22.500	12	B	2.76412	B	3.6968

* Means with the same letter in Duncan groupings are not significantly different.
Critical range X/Y: X Critical range for span 2 ranked averages
Y Critical range for span 3 ranked averages