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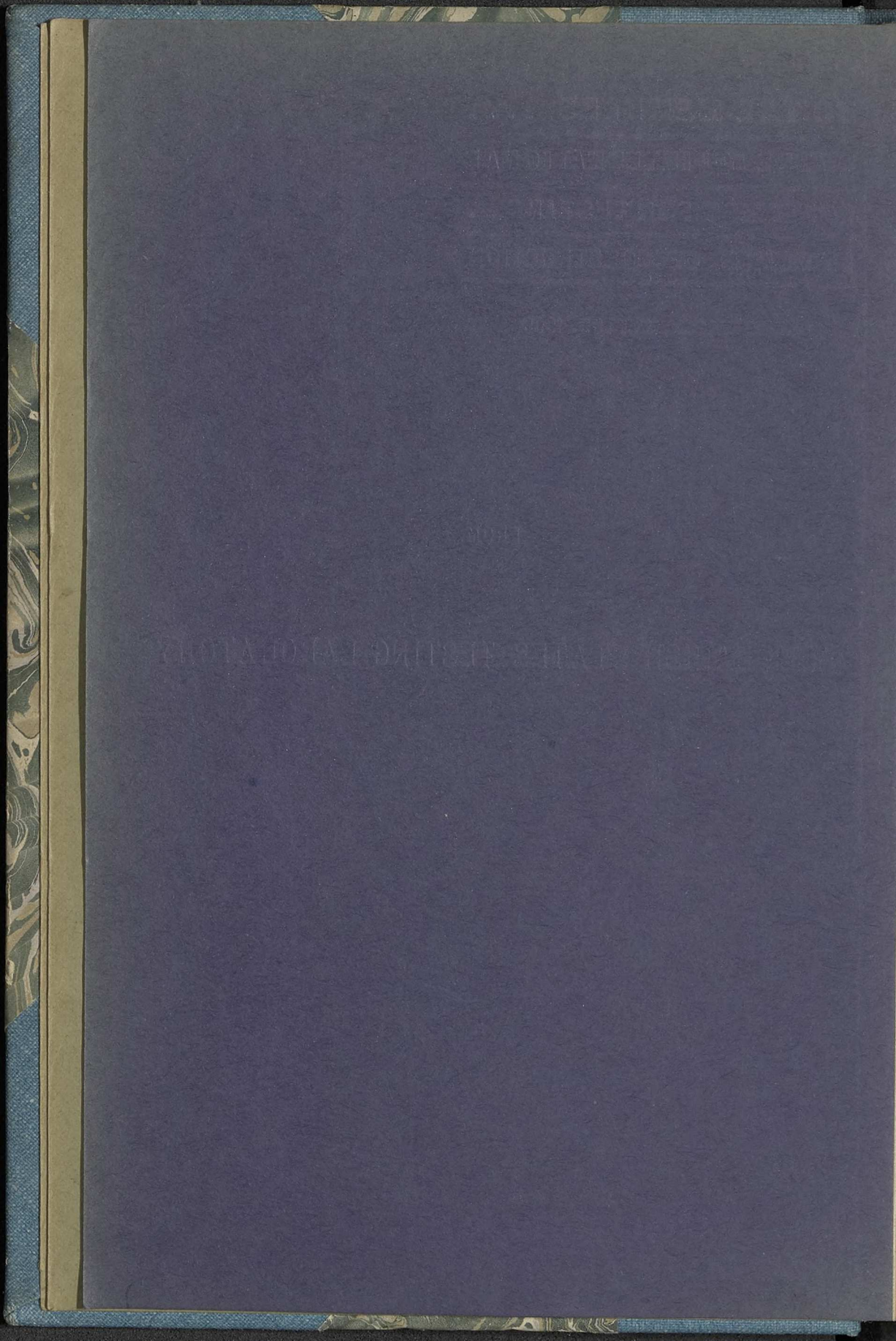
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TO THE MEMBERS.....
OF THE 5TH INTERNATIONAL
CONGRESS FOR TESTING..
MATERIALS OF CONSTRUCTION

COPENHAGEN, SEPTBR. 1909

FROM

THE DANISH STATES TESTING LABORATORY



OM
MATERIALPRØVNINGENS
UDVIKLING I NORDEN

OG
OM STATSPRØVEANSTALTENS VIRKSOMHED

ON THE DEVELOPMENT OF TESTING OF MATERIALS
IN THE NORTH

AND

ON THE WORK OF THE DANISH STATES TESTING
LABORATORY IN COPENHAGEN

(ENGLISH TRANSLATION.)



KJØBENHAVN

TRYKT HOS J. JØRGENSEN & CO. (M. A. HANNOVER)

1909



D' Heer Veldt - Marschalk
PAULUS WURTZ .

Den første, praktiske Materialprøver,
født d. 30. Oktbr. 1612, død d. 24. Marts 1676.

The first who employed testing of materials practically,
born 30. Oct. 1612, died 24. March 1676.

A. Materialprøvningens Udvikling i Norden.

Ved den internationale Kongres for Materialprøvning, som den franske Regering lod afholde i Paris under Verdensudstillingen i 1900, forelaa fra Ingeniør *Frémont* et større, rigt illustreret Arbejde over Materialprøvningens Udvikling¹⁾. Med Ingeniør *Frémonts* Tilladelse har et Udtog af dette været gengivet i den danske Ingeniørforenings Tidsskrift »Ingeniøren«²⁾ i en Afhandling af undertegnede Direktør for Statsprøveanstalten i Kbhvn. Prof. *Hannover*, som samtidig førte Materialprøvningens Historie frem lige til vore Dage.

I denne Afhandling kunde der naturligvis kun i ringe Grad blive Plads til en Omtale af Udviklingen i Norden, som set sammen med Udviklingen i hele Verden jo kun har været af ringe Betydning.

Ved en Lejlighed som den foreliggende, hvor Teknikere fra alle Lande ere samlede i Danmark, turde der imidlertid være Anledning til at vise, hvad der er ydet i Norden, specielt i Danmark, til Materialprøvningens Udvikling.

I. Poul Würtz.

I *Frémonts* ovennævnte, udmærkede Arbejde anføres efter *P. S. Girard*: *Traité analytique de la résistance des solides*, etc. 1798, at *Galilei* var den første, som forsøgte at anvende Mekanikkens Love paa de faste Stoffers Modstandsevne. Det var, da *Galilei* besøgte Arsenalet i Venedig, hvor han i de forskellige Værksteder

¹⁾ Évolution des méthodes et des appareils employés pour l'essai des matériaux de construction.

²⁾ »Ingeniøren« 1908, S. 167.

saa de Maskiner, man konstruerede, at han gav sig til at tænke over denne Modstandsevne. *Galilei* indsaa let, at naar en Cylinder var ophængt lodret, virkede den til at trække sig selv over paa det svageste Sted, og endvidere¹⁾, at den vilde blive paavirket ganske anderledes, hvis den anbragtes vandret med den ene Ende inde i en Mur. Han opstillede en i øvrigt ikke korrekt Formel for de Paavirkninger, den vilde lide inderst inde ved Muren. Han fandt yderligere, at en rektangulær Bjælke var stærkere, naar den laa paa Højkant end paa Fladen, og gav sig endog til at udregne, hvorledes en Bjælke, der var indspændt ved den ene Ende, skulde formes, for at indeholde saa lidt Materiale som mulig i de forskellige Tværsnit, og fandt, at naar Undersiden var vandret, skulde Oversiden formes efter en Parabel.

Frémont anfører i sin Afhandling videre, at *Galilei*, som døde 77 Aar gammel d. 8. Januar 1642, aldrig undlod at gøre opmærksom paa den praktiske Nytte af de Resultater, han kom til, men at han dog ikke gjorde egentlige Materialprøvningsforsøg. *Frémont* skriver efter *Girard*, at de første af denne Slags synes at skyldes en Svensker *P. Wurtzius*, saaledes som det fremgaar af et Brev til ham i 1657 fra den franske Arkitekt *François Blondel*, der efter *Galilei* er den første Skribent om disse Materier, og som selv siger, at han var en af *Galileis* sidste Disciple²⁾.

Ved Offentliggørelsen af *Leonardo da Vincis* store, hidtil uudgivne Manuskript: *Codice atlantico*³⁾, der er fra Aarene omkring 1500, har det dog vist sig, at allerede *Leonardo* har anstillet Styrkeforsøg, saa at *Galilei* ikke er den første, der har skrevet om saadanne, og *Wurtzius* ikke den første, der har udført saadanne. Men *Leonardos* Forsøg, der f. Eks. have drejet sig om, hvor stor Nedbøjning Bjælker faa under forskellig Belastning, have næppe naaet til at prøve Styrkeberegningers Rigtighed i Praksis, eller til at anvende dem.

Da det nu som sagt var angivet, at en Svensker *P. Wurtzius* var den første, praktiske Materialprøver, opfordrede jeg den bekendte Physiker Dr. *Benedicks* ved Upsala Universitetets fysikalske Institut til at søge at fremskaffe nærmere Oplysninger om sin

¹⁾ Af *Galileis* berømteste Værk over Mekanik: *Discorsi e dimostrazioni matematiche*, o. s. v. 1638.

²⁾ Nedenfor nævnte Brev fra *Blondel* til *Sieur B.*, S. 166.

³⁾ Se Prof. *Th. Becks* Afhdlg. i *Zeitschr. des Ver. deutsch. Ing.* 1906, S. 524.

formentlige Landsmand *P. Wurtzius*. I *Frémonts Afhdl.* staar desangaaende dels henvist til *Girard's* nævnte Værk, dels til, at selve Brevet fra *Blondel* staar citeret i »Recueil de plusieurs traités de mathématiques par quelques membres de l'Académie des sciences« in-folio, 1676, hvad der dog har vist sig ikke at være korrekt, — se S. 6, Note 1 nedenfor.

I Novbr. 1908 modtog jeg fra Dr. *Benedicks* et Svar, hvoraf fremgik, at han havde fundet, at efter alt at dømme maatte *P. Wurtzius* være Feltherren, Friherre *Poul Würtz* (*v. Wirtz*), en af Sverrigs bekendte Hærførere. Men tillige viste det sig, at *P. Wurtzius* ikke var svensk af Fødsel, men født i Husum i Sønderjylland (Slesvig), som den Gang var dansk, den 30. Oktbr. 1612.

Samtidig var Dr. *Benedicks* saa god efter Svensk biogr. Lexikon og Nord. Familjebok at meddele en Del Oplysninger om *Würtz's* Liv samt at oplyse, at en Biografi af ham: »Leben und Thaten des Herrn *Paulus v. Wirtzen*« af *Philander v. d. Weistriz* (Pseudonym for *Christ. Gottl. Menzel*) var udgivet i Kbhvn. og Leipzig 1756¹⁾ (oversat fra en hollandsk, original Biografi fra 1681). Endelig tilraadede Dr. *Benedicks* at efterse *Blondels* Skrifter: *Manière de fortifier les places* 1683 og *L'art de jeter les bombes* 1685, angaaende hvilke Emner *Blondel* med Udbytte kunde have korresponderet med *Würtz*²⁾.

Da der saaledes var Sandsynlighed for, at den første, praktiske Udøver af Materialprøvningen var en dansk født Mand, bad jeg Prof. ved Universitetet Dr. *J. A. Fridericia* være mig behjælpelig med nærmere at undersøge Rigtigheden heraf, hvilket han har gjort med stor Beredvillighed.

Prof. *Fridericia* fandt straks paa Universitetsbibliotheket i *Mémoires de l'Académie royale des sciences* 1666—99, T. 5 (Paris 1729, 4to) en Række Afhandlinger af *Blondel* med Fælles-Titlen: *Résolution des quatres principaux problèmes d'architecture*. Det fjerde Problem heri kaldes: *Trouver la ligne sur laquelle les poutres doivent etre coupées en leur hauteur et largeur pour les*

¹⁾ Jvnfr. *Allgemeine deutsche Biographie* XLIV.

²⁾ I alt Fald i den første af disse Afhandlinger findes der dog intet derom.

³⁾ Dette Brev er dateret 1657, pridie Idus Sextilis, 3: 12. August. Naar *Poggendorf* i sin *Wörterbuch* Bd. 1 under *Blondel* anfører en Artikel af ham: *Sur la résistance des solides* i *Mem. Par. T. 1* (hvorved sikkert maa forstaaes

rendre partout également fortes et résistantes. Den første Del heraf hedder: Premier discours ou F. B. epistola ad P. W.³⁾, In qua celebris Galilæi propositio discutitur circa naturam . . . , hvilket betyder: »F. B.'s Brev til P. W., hvori der drøftes *Galileis* berømte Sætning om Formen af den Linie, hvorefter Bjælker bør tildannes, saaledes at de allevegne ere af samme Modstandskraft, og hvori det bevises, at hin Linie ikke er parabolisk, som *Galilei* mente, men elliptisk«.

I denne Afhandling staar der S. 478:

»Perjucunda mihi profecto fuit elegantissima narratio de ad-
»mirabili illa machina qua in Colossicoteri tui Leonis Hyperborei
»constructione uti te dicis, et magnopere me delectat ista con-
»templatio intricatissimæ illius tignorum, rudentum et ferramen-
»torum compagis quæ rectoris imperio ingenioque ita se præstat
»obsequentem«.

Ved Oversættelsen heraf byder Ordet »Colossicoterum« Vanskeligheder. Det synes dog af det følgende at fremgaa, at Talen er om Skibsbygning, og Ordet kan derfor mulig betyde Skrog, og »Leo hyperboreus« 3: den nordiske Løve være Navnet paa et Skib. I saa Fald vilde Oversættelsen lyde:

»Din elegante Fortælling om den mærkværdige Maskine, som
»Du siger, at Du bruger ved Konstruktionen af Skroget til »den
»nordiske Løve« har i Sandhed været mig meget behagelig, og i
»høj Grad fornøjer mig Iagttagelsen af den meget indviklede
»Sammenføjning af Bjælker, Tøve og Jærnværk, som viser sig
»saa lydig mod Lederens Befaling og Talent«.

Videre hedder det S. 478:

»Quod autem scribis, sectas a te ex præscripto Galilæi linea
»parabolica secundum altitudinem trabes, ut æqualis ubique
»forent resistantiæ, non omnino expectationi tuæ respondisse . . .«,
hvilket betyder:

»Hvad Du skriver, at de Bjælker, der ere formede af Dig
»efter *Galileis* Forskrifter efter en Parabel i Højden, ikke har svaret
»til Din Forventning om, at de allevegne skulle være af samme
»Modstandsevne«.

Mémoires de l'Académie de Paris), maa det efter *Fridericias* Mening være en Fejl, da en saadan Artikel ikke findes i T. 1 men i T. 5.

Blondel fortsætter med at sige, at dette i Begyndelsen har undret ham, men at han nu har opdaget, at *Galilei* har taget fejl.

S. 486 skriver han: »Atque ex istis omnibus patet ratio, cur »nimiam quam in Galilæum habebas fiduciam experimenta tua »deluserunt«, hvilket betyder:

»Af alt dette fremgaar Grunden til, at Dine Eksperimenter »har skuffet Din altfor store Tillid til *Galilei*«.

Dette er saa vidt vides det første Sted i nogen trykt Bog, hvor der tales om Materialprøvningsforsøg.

S. 493 skriver *Blondel*: »Etiam atque etiam te rogo ad me »quam primum rescribe quid sentias, factis præsertim, ea qua »soles sedulitate atque solertia experimentis«.

Her skriver *Blondel* altsaa paany om *P. W.*'s Eksperimenter, idet Betydningen er: »Atter og atter beder jeg Dig, skriv snarest »til mig, hvad Du mener, især naar Du har gjort Eksperimenter »med Din vante Flid og Duelighed«.

Spørgsmaalet bliver nu: Er *P. W.* den bekjendte Feltherre *Würtz*?

Würtz's Navn er jo nemlig ikke nævnet, men Prof. *Fridericia* antager det for sikkert, at det er ham, der menes, thi i Indledningen til Brevet taler *Blondel* om, at han ikke har kunnet besvare *P. W.*'s Skrivelse, fordi *W.*'s Herre er fløjet fra Sarmaterne (o: Polakkerne) til Cimbrerne¹), hvorved maa hentydes til Karl Gustavs Tog fra Polen til Danmark i Juli 1657, idet *Würtz* deltog i svensk Tjeneste i dette Tog.

Den anden Del af *Blondels* 4de Problem, der er paa fransk, medens første Del er paa Latin, har næppe noget med *P. W.* at gøre. Den har Titlen: Second Discours ou Lettre au Sr. (Sieur) B. pour la résolution de ses doutes sur les Propositions du premier Discours. Den er dateret Paris, 18. Juli 1661. *Blondel* omtaler i øvrigt i dette Brev, at han for mere end 12 Aar siden har skrevet et Værk: Galilæus Promotus de resistentia Solidorum, som han dog endnu ikke har udgivet. Brevet begynder saaledes: Monsieur. Je vous suis parfaitement obligé du soin que vous avez pris, de me donner part des remarques, qui ont esté faites sur une Lettre, que j'écrivis il y a quelques années a un de mes

¹) Nam a quo tempore a Sarmatis ad Cimbros evolavit Heros vester . . . ,

Amis en Suède Her er aabenbart Forklaringen paa, at Würtz senere er gaaet for at være en Svensker.

Det lykkedes videre Prof. *Fridericia* paa det store kgl. Bibliothek at finde en tysk Oversættelse af *Girards* af *Frémont* nævnte Bog (Katalog 51, S. 23), som hedder: *P. S. Girard: Analytische Abhdlg. von dem Widerstande fester Körper, und von den Körpern von überall gleichem Widerstande, a. d. Franz. übers., Giessen 1803, 4^{to}. I dens Indledning staar paa S. X:*

»Was seine (o: *Galileis*) Hypothese über die Cohärenz der
 »Körper betrifft, so muss hier bemerkt werden, dass er sie durch
 »keine Versuche bestätigt hat. Unter den Schülern, welche in
 »seinen Werken die Elemente einer neuen Wissenschaft studierten,
 »hätte sich doch wohl irgend einer finden sollen, der es unter-
 »nommen hätte, diese Hypothese durch Versuche zu begründen,
 »um so mehr, da Galilei es niemals unterliesz, die Nützlichkeit
 »seiner Theorie für die mechanischen Künste durch Beispiele
 »anschaulich zu machen. Demungeachtet aber wurden die ersten
 »Versuche über den Widerstand fester Körper nicht in Italien
 »angestellt, sondern wir sind sie einem Schweden Namens
 »*P. Wurtzius* schuldig, wie aus dem Briefe hervorgeht, den er
 »1657 ¹⁾ an *François Blondel* schrieb. Dieser französische Baumeister
 »war der zweyte, der über diese Materie schrieb. Es scheint,
 »dass er sich nicht sehr geeilt habe seine Entdeckungen bekannt
 »zu machen, denn in einem Briefe an W. vom Jahre 1661 ²⁾ sagt
 »er, dass er schon 1649 ein Werk über den Widerstand der festen
 »Körper unter dem Titel: »*Galilaeus promotus*« geschrieben habe«.

Angaaende *Poul Würtz's* Levnet giver Dansk biografisk Lexikon, 19de Bd., S. 248 meget interessante Oplysninger. Man erfarer deraf, hvorledes han, der var født i Husum d. 30te Oktbr.

¹⁾ Under Teksten staar der: Dieser Brief ist in einer von mehreren Mitgliedern der Akad. der Wissensch. veranstalteter Sammlung mathematischer Abhandlungen angeführt (in Folio 1676). Hermed menes sikkert det forud omtalte Værk: *Recueil de plusieurs traités o. s. v.*, men i dette Værk, som haves paa Universitetsbibliotheket, findes der ingen Omtale af *Blondel* eller *Würtz*.

Girard, som ses at have været Kilden for *Frémonts* Meddelelser om *Würtz*, maa da vistnok have begaaet en Fejl ved sin ovenfor anførte Passus paa S. X i Indledningen, sandsynligvis ved at overse, at *Blondels* Breve af 1657 og 1661, som ere omtalte ovenfor, ere til to forskellige Personer.

²⁾ Under Teksten staar der: F. B. epistola ad P. W. in qua famosa Galilaei propositio discutitur circa naturam

1612 og Søn af en derboende Borger *Claus W.* og *Margrethe Busch*, var i Besiddelse af en brændende Videbegærlighed og en stor Energi og, da han havde faaet Ansættelse som Skriver hos en Advokat i Slesvig, anvendte al sin Fritid til at stille sin Kundskabstrang. Videre, hvorledes Skæbnen var ham gunstig, saa at han kom i Berøring med en kejserlig Kaptain, der var afsendt til det gottorpske Hof, og som fattede Godhed for ham og tog ham med til Wien, hvor han lod Jesuiterne opdrage ham. *Würtz's* Hu stod imidlertid til Krigergerningen, og han lod sig derfor hverve til Soldat og tjente sig op til Løjtnant, men for at faa hurtigere Avancement gik han i svensk Tjeneste, hvor han i Karl Gustav af Zweibrücken — den senere svenske Konge Karl X — vandt en mægtig Ven og Beskytter, der forstod at værdsætte hans Kløgt, Mod og Snarraadighed og lod ham stige fra Grad til Grad, saa at han ved Afslutning af Trediveaarskrigen stod som Oberst og Chef for den svenske Livgarde til Hest. En nærmere Omtale finder hans Deltagelse i Karl Gustavs Krige i Polen, efter hvilke han blev udnævnt til Generallieutenant og Friherre og forlenet med Godset Ørnholm i Kexholm Len og ansat som Guvernør i Stettin. Hans Korps rykkede op gennem Holsten og Slesvig og deltog i Stormen paa Frederiksodde 24. Oktbr. 1657. Efter senere at have følt sig tilsidesat i Sverrig og være flyttet til Hamborg for at leve som Privatmand, modtog han en Opfordring til at træde i sit Fædrelands Tjeneste, og i Januar 1665 udnævntes han til dansk Feltmarschal og blev i Juli s. A. kommanderende General i Hertugdømmerne og Fyrstendømmerne. Men da en Fredsperiodes magelige Liv ikke i Længden tilfredsstillede en Kriger, der var bleven graa paa Slagmarken, gik han i hollandsk Tjeneste, idet han allerede d. 31. Oktbr. 1665 erholdt Afsked af dansk Tjeneste. I 1674 trak han sig tilbage til Privatlivet og døde i Hamborg Natten mellem d. 23. og 24. Marts 1676.

I *Müllers* Pinakothek Bd. XII, S. 104 paa det kgl. Bibliothek findes *Würtz's* Portræt. Dette er gengivet foran (Fig. 1).

Statsprøveanstalten har ønsket at begynde denne Afhandling om Materialprøvningens Udvikling i Norden med at drage frem af Glemselens Slør, at vort Fædreland har Æren af at have fostret den Mand, der, saa vidt vides, var den første til at gøre Materialprøvningsforsøg i praktisk Øjemed.

Poul Würtz, hvis Liv jo i øvrigt væsentlig tilhører Sverrig, bør regnes for en af Nordens store Mænd.

II. Materialprøvningens Udvikling i Sverige.

I det 18de og 19de Aarhundrede er det af de nordiske Lande særlig Sverrig, som har Æren af at have bidraget til Materialprøvningens Udvikling, medens Materialprøvningens Udvikling i Norge og Finland har været af mindre Betydning.

Swedenborg beskriver i sin Bog »De Ferro« 1734 de Forsøg, f. Eks. Bøjningsforsøg, som Købmændene gjorde, naar de købte svensk Jærn.

I 1826 lod den svenske Assessor *P. Lagerhjelm* i Stockholm anstille sammenlignende Forsøg mellem udsmedede og valsede Jærnstænger. Undersøgelserne bleve i 1827 offentliggjorte i Jærnkontolets annaler.

Af senere Forsøg turde nogle af de vigtigste være de Undersøgelser over Jærnbane-materialier¹⁾, som *Knut Styffe* gjorde i Tredserne for en Komité, der var nedsat, formodentlig i Anledning af, at en Jærnbanevogn med Kong Karl den 15de var løbet af Skinnerne formedelst Brud paa en Hjulbandage. *Knut Styffe*, der endte som Overdirektør ved kgl. tekn. Högskolan i Stockholm i 1897, og som paa den internationale Materialprøvningskongres i Stockholm i 1897 blev hilset af dens Præsident, Prof. *v. Tetmajer*, som »Materialprøvningens Nestor, hvis Forsøg nu ere klassiske«, fandt ved sine Undersøgelser blandt andet, at Grunden til de mange Brud paa Hjulbandager og Jærnbaneskinner om Vinteren for en væsentlig Del skyldes den frosne Jordbunds Stivhed.

Af senere svensk Forskning maa særlig nævnes *Brinells* berømte Undersøgelser om Staalets Strukturforandringer ved Opvarmning og Afkøling, samt hans nu saa omtalte Haardhedsprøve, *Wijkanders* over Træs Styrke, *Sellergrens* Slagforsøg og Forsøg med skærende Værktøj, Forsøg af *Svedelius*, *Wahlberg* og *Braune* over Jærn og Staal, Dr. *Benedicks'* over Jærns og Staals Mikrostruktur, m. m., o. s. v.

En interessant Oversigt over Sverrigs Ydelser paa Materialprøvningens Omraade blev givet paa den internationale Materialprøvningskongres, »Hållfasthetskongressen«, i 1897 i Indledningen

¹⁾ *Knut Styffe*: Om jerns och ståls elasticitet, tånjbarhet och absoluta styrka, Stockholm 1866.

til det af Järnkontoret udgivne Arbejde: »Hållfasthetsprof å svenska Materialier«, der ogsaa udkom paa tysk.

Sverrig har som bekendt nu to Prøveanstalter, nemlig en ved kgl. tekn. Högskolan i Stockholm og en ved Chalmersska Institutet i Gøteborg.

III. Materialprøvningens Udvikling i Danmark.

I Danmark er der saa vidt vides første Gang skrevet indgaaende om Materialprøvning af *Jens Kraft* i hans store Mekaniks 2det Bind 1764¹⁾.

Men allerede tidligere havde Materialprøvningen fundet Vej her til Landet. I *Carl Bruun*: Kjøbenhavn, 3die Del, 1901 S. 48 omtales, hvorledes der ved Gammelstrand udfor Naboløs i 1761 opsattes en »Skijsanker-Prøve-Machine«, bestaaende af en 30 Fod høj Pæl, fra hvilken ethvert Anker ved sin egen Vægt skulde falde ned paa en underliggende Kanon uden at beskadiges. Prøven og den paafølgende Stempling, som naturligtvis ikke løb af uden Udgifter, stødte paa stærk Modstand hos Ankersmedene; de nægtede rentud at afhænde deres Varer, hvis de skulde prøves, eller vedblev at sælge ustemplede Ankere. I 1764 idømtes Ankersmed Christen Jochumsen Lund en Bøde paa 1,000 Rdlr. for denne Forseelse (han slap dog med at betale 100), og det oplystes ved samme Lejlighed, at det asiatiske Kompagni aldrig lod sine Ankere prøve og stemple.

For at tilvejebringe en samlet Oversigt over, hvad der er ydet paa Materialprøvningens Omraade her i Landet, har jeg henvendt mig til Ingeniørkorpset, Statsbanerne, Direktøren for Artilleriets tekn. Tjeneste, Orlogsværftet og Statens tekn. Bureau for Papirundersøgelser med Anmodning om at staa Statsprøveanstalten bi med Oplysninger derom. Idet jeg takker disse Institutioner for deres Redebonhed i saa Henseende, gengiver jeg her de modtagne Oplysninger samt nogle andre Oplysninger, navnlig om Statsprøveanstalten.

a. Oversigt over de under Ingeniørkorpset i Aarene 1858—1880 udførte Forsøg vedrørende Portlandcement og Beton²⁾.

Da man i Begyndelsen af afvigte Aarhundrede begyndte at anvende Murkonstruktioner paa Søforterne ved Kjøbenhavn,

¹⁾ Se nærmere i »Ingeniøren« 1908, S. 186.

²⁾ Af Ingeniørkaptajn L. Madsen.

maatte de Ingeniørofficerer, som ledede Arbejderne, anstille Forsøg for at afgøre, hvorledes den Mørtel, der var udsat for Havets Angreb, hensigtsmæssigst skulde sammensættes. Fra Aaret 1845 paabegyndtes Udførelsen af samlede Forsøgsrækker med Prøver af forskellige hydrauliske Mørtler. Disse Forsøg udførtes ved at



Fig. 2. General J. F. M. ERNST,
født i Kbhvn. 1820, død dér 1897.

tildanne Prøvestykker af forskellige Mørtelblandinger, som efter endt Størkning udlagdes i Søen, hvor de holdtes under Observation gennem en Aarrække.

Da Ingeniørkorpset i 1857 overdrog daværende Kaptajn *Ernst* (Fig. 2) at udarbejde Forslag til en Udvidelse af den eksisterende Søbefæstning om København, optog Kaptajnen de ældre Forsøgsrækker i udvidet Form, og inddrog særlig Portlandcement under Undersøgelsen.

Fra den 15. April 1858 begyndte man tillige at udføre Styrkeprøver ved Sønderrivning af Mørtellegemer.

Ved disse indledende Forsøg var Opmærksomheden bleven henledet paa Portlandcementens gode Egenskaber, og da der samtidig opstod Frygt for, at Pæleormene for hurtigt skulde ødelægge Trækstrukturen i Søforternes Underbygning, blev Kajindfatningen i Havnen ved Fortet Prøvesten udført som en Mur af Blokke støbt af Portlandcementbeton med Granitskærver.

Da man ved anstillede Forsøg straks fra Begyndelsen havde opnaaet at forfærdige Betonen paa rette Maade, baade i Henseende til Blandingsforhold, Blandings Udførelse og Stampning, viste Blokkene under Transporten og Udlægningen en saa stor Styrke, at Kaptajn *Ernst* stillede Forslag til Ingeniørkorpset om at forsøge, hvorvidt Beton vilde vise større Modstandsevne mod Beskydning end det Murværk af brændte Sten i Cement-Kalkmørtel eller kløvede Granitsten i Cementmørtel, der var paaregnet anvendt ved Bygningen af Fortet.

I den Anledning udførtes i 1860 og 1861 Skydeforsøg mod Murværk af ovennævnte Arter, og ved disse viste Betonen sig i Besiddelse af en langt større Elasticitet og Sammenhængskraft end de andre Arter af Murværk. (Beskrivelse af Forsøgene foreligger i »Oversigt over Artilleriets Forsøg II« 1866). Det besluttedes derfor at udføre Fortet helt af Beton, og dette Materiale blev derefter anvendt i de øvrige Søforter og — om end af Bekostningssyn i ringere Omfang — i de provisoriske Skanser paa Dybbøl.

Uagtet man i Udlandet blev bekendt med denne Bygningsmaade (se eksempelvis Stettiner Portland-Cementfabrikkens 50 Aars Jubilæumsskrift), blev den dog ikke optaget andetsteds, før Artilleriets Udvikling c. 20 Aar senere tvang til at forlade de ældre Murmaterialer og gaa over til Portlandcementbetonen som Hovedbygningsmateriale i Krigsbygningskunsten.

Ved Opførelsen af de nye Søforter og ved Forstærkning af de ældre blev der anvendt betydelige Mængder Cement, som leveredes af forskellige tyske, engelske og senere tillige danske Fabrikker. Allerede fra Aaret 1858 blev enhver modtagen Skibsladning underkastet en omhyggelig Undersøgelse i Henseende til Bindetid, Rumfangsbestandighed, Litervægt og Styrke.

Styrkeforsøgene var i Tidsrummet 1859—1867 væsentligst

Sønderrivningsforsøg; dog begyndte man allerede 1860 at udføre Knusningsforsøg, og fra 1867 udførtes Knusningsforsøg jævnsides med Sønderrivningsforsøgene. Der anvendtes Prøvelegemer af ren Cement og af Mørtel i forskellige Blandingsforhold, og Forsøgene udstraktes 1 à 2 Aar for hver Leverance, hvorved man fik et godt Kendskab til Hærtningsforholdene.



Fig. 3. Oberst A. J. C. KEYPER,
født 1833.

I Tidsrummet fra 1858—1873 ledes Forsøgsarbejdet af nuværende Oberst A. J. C. Keyper (Fig. 3), der har givet en Fremstilling af disse og deres Resultater i »Maanedsskrift for tekniske Meddelelser, udgivet af Industriforeningen i København«, 8. Aargang 1873.

Fra 1876—1880 udførtes Forsøgene af daværende Premierløjtnant A. F. C. C. Andersen (Fig. 4), der dels forbedrede Undersøgelsesmetoderne, dels konstruerede nye Prøveapparater. Resultaterne

af hans Arbejder findes i »Den tekniske Forenings Tidsskrift« 1877—78 og 1880—81. Det skyldes ham, at der allerede i de ældste danske Normer for Cementundersøgelser (1878) findes optaget Bestemmelser for den Tid, som ved Sønderrivningsforsøgene med Mørtellegemer bør forløbe mellem Forsøgets Begyndelse og Bruddets Indtræden.



Fig. 4. Ingeniørkaptejn A. F. C. C. ANDERSEN,
født 1848, død 1892.

Ved de danske Normer for Cementprøvningen af 1889 fastsattes større Dimensioner for Prøvelegemer til Knusningsforsøg end de af Ingeniørkorpset hidtil anvendte. Da Ingeniørkorpsets Prøveanstalt paa Kvintus ikke forsynedes med de dertil svarende Prøvemaskiner, har Anstaltens Resultater fra senere Tid kun Værdi for Korpsets egen Tjeneste.

Anstaltens ældste Arbejder har haft den Betydning, at de har ledet til rigtigt Valg af Bygningsmateriale for Konstruktioner af

stor pekuniær Interesse. De følgende Arbejder har haft en vis Indflydelse paa Cementfabrikationens Udvikling, idet de tidligt har ansporet Fabrikkerne til at yde det bedste, de formaaede, ved Leverancer til det danske Ingeniørkorps. De afgiver tilsammen et Eksempel paa Materialundersøgelsernes praktiske Værd.

b. Oversigt over Materialprøvningen ved de danske Statsbaner.

Ved Baneafdelingen foretages Prøver af Skinner og Forbindelsesdele samt af Bygningsjærn og Cement efter de sædvanlige Normer.

Ved Maskinafdelingen foretages følgende Materialundersøgelser ¹⁾:

Kautschuk. Askebestemmelse. Undersøgelse af i 5 % Natron-Alkohol opløselige Stoffer. Forhold ved Ophedning i Damp ved 5—15 Atm. Forhold ved stærk Afkøling. Bøjeforsøg med Varmeslanger.

Kul. Bestemmelse af Aske, Svovl og flygtige Bestanddele. Bestemmelse af Varmeværdien.

Olier. Bestemmelse af Vægtfylde, Flammepunkt, Brændetemperatur, Syreindhold. Opsugningsevne ved lave Temperaturer og øvrige Forhold ved Temperaturer under 0°. Asfaltbestemmelse, Fordampning ved Temperaturer i Nærheden af Flammepunktet og Asfaltforøgelsen herved.

Jern og Staal. Styrkeprøver, Bøje- og Hærdebøjeprøver, Stukkeprøver, Lokkeprøver og Svejseprøver.

Blad- og Evoluttfjedre. Undersøgelse af Elasticitet.

Andre Metaller. Styrkeprøver. Analyser, dels elektrolytiske.

Tekstilvarer. Styrkeprøver. Mikroskopiske Undersøgelser.

Asbest- og anden Pakning. Overrivningsprøver. Behandling med højspændt Damp.

Asbestvæv og Fibre til Isolation. Bestemmelse af Vægtfylde. Bestemmelse af Indhold af organiske Stoffer.

Svovlsyre til Akkumulatorbrug. Undersøgelse om Tilstedeværelse af Arsen og Chlor. Styrkebestemmelse.

Destilleret Vand. Undersøgelse om Tilstedeværelse af Chlor.

Blymønnie, Sølvglød til Akkumulatorbrug. Be-

¹⁾ Efter Oplysninger af Maskindirektør Busse.

stemmelse af uopløselige Stoffer. Bestemmelse af Blyilte. Undersøgelse for Kobber og andre tunge Metaller.

Vand til Lokomotiver og stationære Kedler. Fuldstændig Analyse.

Kondensationsvand i Skibe og Færger. Bestemmelse af Chlor- og Fedtindhold.

Malervarer til Skibe og Færger. Bestemmelse af Jærnilte, Kvægsølv, Arsen og Kobber.

Af de af Maskinafdelingen udarbejdede Undersøgelsesmetoder tør følgende maaske paaregnes at være af større Interesse:

Undersøgelsen af Kul, som nærmere beskrevet i Nr. 34/1906 af »Ingeniøren«.

Bestemmelse af Materialiers Haardhed ved Inddrievning af Staaalskiver i Materialet og derefter følgende Udmaalning af det Mærke, der er frembragt i Materialet. De til disse Forsøg benyttede Apparater ville eventuelt kunne forevises og forklares paa Kongressen.

c. Oversigt over de ved Artilleriet udførte Materialprøver¹⁾.

Til Undersøgelse af det ved Artilleriet anvendte Materiel og de til dettes Fremstilling benyttede Materialier udføres der aarlig en stor Mængde Prøver, der dels som Smede- og Hærdeprøver og lignende udføres ved de forskellige Værksteder, dels som Skudprøver udføres i Forsøgskommissionen, og ved Haandvaabenkontrollen, Skydeskolen og Laboratorieværkstederne, medens alle Stræk-, Slag- og Bøjep prøver samt kemiske Analyser udføres ved Artilleriets Prøveanstalt.

Ved denne er der i Aaret $1\frac{1}{7}$ 1907— $30\frac{3}{6}$ 1908 udført:

122 Strækprøver paa forskellige Materialier saasom Staal, Støbejern, Kobber, Messing, Staaltraadstove, Hampetove og Amyantine.

37 Slagprøver paa Staal og Støbejern.

20 Bøjep prøver paa Staalrør.

139 kemiske Analyser til Undersøgelse af forskellige Staal-sorter, Kobber og Kobberlegeringer, Bly og Blylegeringer navnlig Haardtly, Tin, Zink og Aluminium samt Amyantine, Silkesnor,

¹⁾ Efter Oplysninger af Premierlieutenant Ove K. Ovesen, Chef for Artilleriets Prøveanstalt.

Silketraad, Flonel, Vaselineolie, fast Vaseline, Ferronat og andre Fedtstoffer.

Foruden disse Undersøgelser er der ved Artilleriets Prøveanstalt i nævnte Aar foretaget et meget stort (530) Antal Bestemmelser af Fugtighedsindholdet i Krudt, medens alle egentlige Krudt- og andre Sprængstofundersøgelser er udført ved Frederiksværk Krudtværk.

Det kan iøvrigt oplyses, at Artilleriet allerede paa et ret tidligt Tidspunkt foruden Skudprøver har anvendt andre Materialprøver ved Undersøgelsen og Bedømmelsen af de til Skytset og Ammunitionen anvendte Materialier.

I Aaret 1771 blev der saaledes paa Københavns Tøjhus ved Hjælp af den derværende saakaldte store nürnbergske Vægt gjort Strækprøver for at bestemme Styrken af Kanonmetal, hvis Legering noget senere — i Begyndelsen af det 19. Aarhundrede — undersøgtes ved Analyser paa Metal af flere forskellige Bronzekanoner.

I Aaret 1805 var der som Modtagelsesprøver for Vognaksler af Jærn fastsat bestemte Slag- og Faldprøver, ligesom der ogsaa i Begyndelsen af det 19. Aarhundrede anvendtes Slag- og Faldprøver ved Modtagelsen af Granater og Bomber.

Der anvendtes ogsaa Slagprøver ved Modtagelsen af Kanoner. Saaledes blev der ved Modtagelsen af 47 Stykker 84 Pd.s Jærnkanoner paa Stafsjø i Sverrig i Aarene 1835—36 udført fuldstændige Slagprøver, idet to Prøvestænger for hver Kanon, een med cirkulært og een med kvadratisk Tværsnit, anbragtes med en bestemt Afstand mellem de understøttende Kanter og bearbejdedes med en Faldhammer af bestemt Vægt og med voksende Faldhøjder, indtil Stængerne blev slaaet over.

Iøvrigt blev der under Støbningen af Kanonerne henhørende til Skytssystemet af 1834 samtidig med hver Kanon udstøbt een eller flere Prøvestænger, der sloges over med en Hammer, hvorefter Jærnets Haardhed bedømtes efter Slagets Styrke og Brudfladernes Udseende; derpaa afdrejedes af Prøvestængerne Skiver, paa hvilke Jærnets Vægtfylde bestemtes. Disse Prøver anvendtes, indtil man i Aarene 1877—78 begyndte tillige at undersøge Jærnets Godhed ved Strækprøver, hvorefter man gik over til at anvende dem.

d. Oversigt over de ved Orlogsværftet udførte Materialprøver ¹⁾.

I tidligere Tid havde Orlogsværftet som Regel egne særlige Bestemmelser for Prøver af de vigtigere Materialier, som bleve leverede til dets Brug, saasom Jern, Staal og andre Metaller, Træ, Kul, Sejldug m. m., og der blev da af og til foretaget Materialprøvningsforsøg for at udfinde den bedste Maade til at sikre sig den til Orlogsværftets Brug fordelagtigste Kvalitet af Materialierne.

I de senere Aar er man imidlertid hos os paa Grund af, at de allerfleste vigtigere Materialier indforskrives fra Udlandet, efterhaanden gaaet over til ved saavel mekaniske som kemiske Materialprøver, at følge de Prøvebestemmelser, der gælde i de større Landes Mariner og da fortrinsvis Bestemmelserne for Marinen i det Land, hvorfra Varen leveres. Ved denne Fremgangsmaade er der vundet i Økonomi og paalidelig Levering, idet de større udenlandske Fabrikanter have lettere ved at levere Materialier, der skulle svare til samme Fordringer, som opstilles af en stor Forbruger som Landets egen Marine, i Stedet for at skulle levere de af os begærede Materialier, der aldrig ville dreje sig om forholdsvis store Partier, efter særlige af os opstillede Prøvebetinger.

Som Følge af den hernævnte Fremgangsmaade, der i det Hele har vist sig fordelagtig for Orlogsværftet, er der ikke i længere Tid bleven udført Materialprøvningsforsøg, som kunne have Interesse for Medlemmerne af Kongressen.

e. Oversigt over de ved Statens tekniske Bureau for Papirundersøgelse udførte Prøver ²⁾.

Statens tekniske Bureau er oprettet 1888 og har siden den Tid undersøgt Papir til Statens Brug, derimod ikke udført Prøver for Private. Prøverne have omfattet Bestemmelse af Papirets Styrke, Modstand mod Krølning og Falsning, samt Askebestemmelse og mikroskopisk Undersøgelse, alt efter de almindeligt brugte Metoder.

Endvidere har man undersøgt Blæk og lignende.

¹⁾ Efter Oplysninger af Direktøren ved Orlogsværftet *I. C. Tuxen*.

²⁾ Efter Oplysninger af Prof. *K. Prytz* og Bestyrer *Chr. Christensen*.

f. Forskellige andre Oplysninger.

I øvrigt er der drevet Materialprøvning flere andre Steder. Hvad saaledes Undersøgelser af Træ angaar, offentliggjorde Forstassistent *E. Hornemann* i Tidsskrift for Skovbrug Bd. XI, 1889: »Nogle Undersøgelser over dansk Rødgran-Veds tekniske Egenskaber«, som han havde udført med Statsunderstøttelse. Hans Arbejde blev efter Forslag af Professorerne *Oppermann* og *Prytz* ved den kgl. Veterinær- og Landbohøjskole efter hans Død fortsat af Forstkandidat *C. V. Meldahl*, som offentliggjorde: »Nogle Undersøgelser over dansk og fremmed Naaletræs Styrke« i Tidsskrift for Skovvæsen, Bd. V, 1893. Ved Prøverne fandtes, at dansk Rødgran ikke stod meget tilbage for svensk eller tysk i Styrke og nærmest kun i de indre Lag. *Meldahl* gjorde ogsaa Undersøgelser over Træs Modstand mod Slid og brugte derved formentlig første Gang Sandblæsning i Materialprøvningens Tjeneste, se Afsnit B III, i.

For et Par Aar siden er der oprettet et forstligt Forsøgsvæsen. Se i øvrigt ogsaa Slutningen af Afsnit B III, k.

Endvidere er der udført Materialprøvning ved Telegrafvæsenet og forskellige Laboratorier og Fabriker, samt Cementprøvning ved *V. Steins* Laboratorium, og ved den polytekniske Lærestalt paabegyndtes der for en Snes Aar siden en Række Undersøgelser over indenlandsk Bygningskalk, der senere fortsattes med nogle Undersøgelser over indenlandsk Portlandcement. Disse Undersøgelser udførtes af Ing. *N. P. Nielsen*. Efter deres Afslutning i 1894 bestod der i et Par Aar ved den sidstnævnte Anstalt et af ham ledet Statslaboratorium for Cementundersøgelser¹⁾, men baade dette og *V. Steins* Cementlaboratorium gik i 1896 op i Statsprøveanstalten.

g. Oplysninger om Statsprøveanstalten og dens Virksomhed.

Statsprøveanstalten er oprettet 1896 af Dansk Ingeniørforening særlig ved dens daværende Formand, nuværende Direktør for den polytekniske Lærestalt, *G. A. Hagemann's* energiske Initiativ. Foreningen forpligtede sig til at dække et eventuelt Underskud

¹⁾ Om de deri udførte Forsøg for Ingkpt. *Grut* over Betons Elasticitet for Træk, se Kongresberetning IX 1 c.

ved Driften, naar Staten vilde tillade Anstalten at føre Navnet Statsprøveanstalten og vilde give den et ringe, aarligt Tilskud.

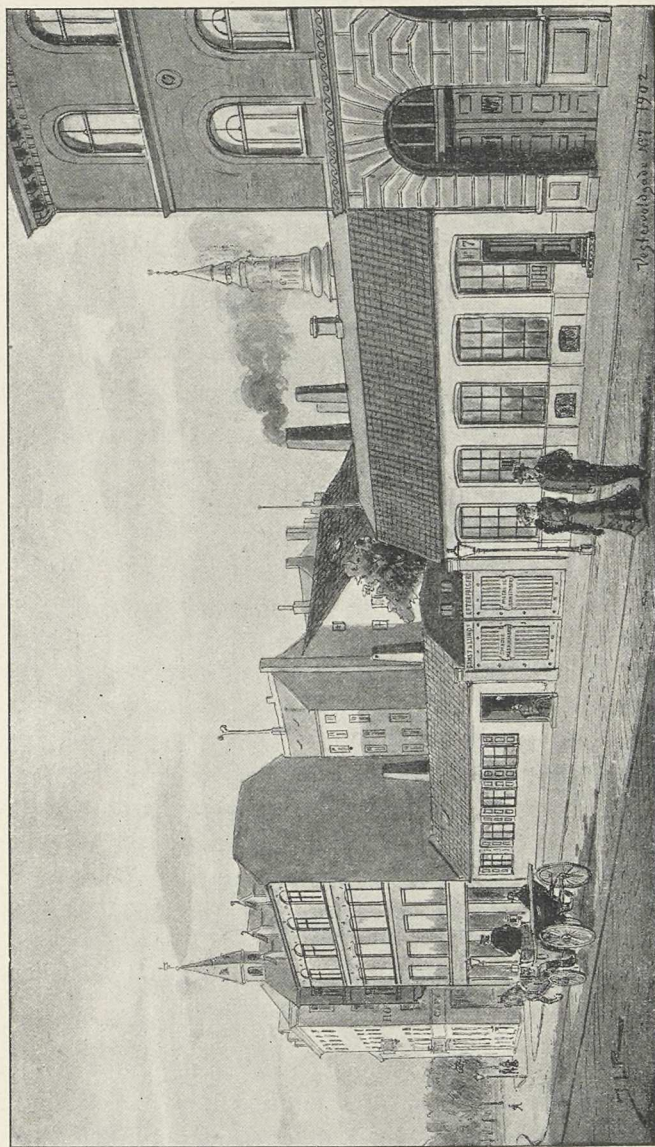


Fig. 5. Statsprøveanstalten i Vestervoldgade 7.

Under denne Form blev Statsprøveanstalten drevet indtil indeværende Aars 1. April, da Staten fuldstændig overtog Anstalten, idet

Hs. Exc. Indenrigsminister *Kl. Berntsen* gennemførte en Lov derom.

En særlig Afdeling af Statsprøveanstalten: Lerlaboratoriet, der var oprettet for Midler skænkede af *Skrikes Stiftelse*, og som havde sin egen Styrelse, gik ved denne Lejlighed op i Statsprøveanstalten.

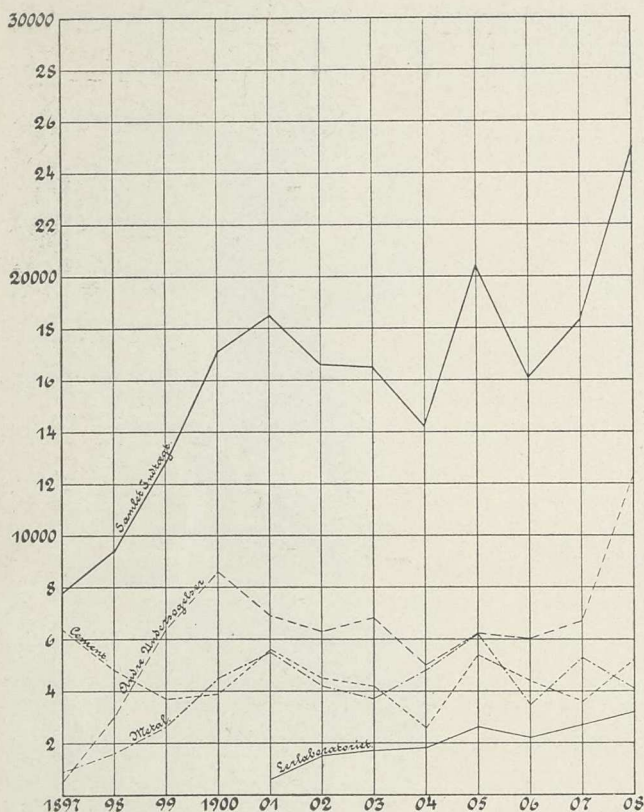


Fig. 6. Grafisk Fremstilling af Variationen i Anstaltens Indtægt af Prøver.

I Fig. 5 ses tilhøjre, under hvor beskedne Forhold Statsprøveanstalten begyndte sin Virksomhed i 1896. Selv endnu boer den kun under smaa Forhold tilleje i en almindelig Privatejendom i Malmøgade 7. Anstalten er teknisk Konsulent for det danske Toldvæsen. I et Lokale, der støder op til Anstaltens Lokaler har den polyt. Læreanstalt et Øvelseslokale for Materialprøvning.

I Aarenes Løb er Statsprøveanstalten kommen i Besiddelse af følgende Materiel:

En fuldstændig Ekviperung til Cementundersøgelse, derunder en 32 Ts. Presse fra *Amsler-Laffon*, et *Ferets* Bøjeapparat m. m.

En 50 Tons Styrkeprøvemaskine for Træk, Tryk og Bøjning fra *Tinius Olsen* i Philadelphia.

En 120 Ts. *Brinck & Hübners* Presse.

En Slidprøvemaskine, System: *Dorry*¹⁾.

Et Vægtstangsapparat til Trykprøvning af Cement- og Lerrør.

Desuden: En elektrisk Ovn — se Side 36 — og andre Ovne til Lerundersøgelser, en *Berthelot-Mahlers* Bombe og forskellige andre mindre Apparater.

Endskønt Anstalten saaledes kun er beskedent udstyret i Forhold til Udlandets store Anstalter, har der dog i Aarenes Løb kunnet gøres løbende Undersøgelser for c. 200000 Kr., og det er saaledes Materialier til ganske store Værdier, der ere prøvede ved Anstalten.

Tilyæksten i Anstaltens Virksomhed fremgaar af Fig. 6, hvor Ordinaterne angive Aarsindtægten for udførte Prøver i de forløbne 12 Aar i Tusinder af danske Kroner. Anstaltens trykte Takster omfatter 285 forskellige Undersøgelser.

Anstalten har hvert Aar udgivet en Aarsberetning i »Ingeniøren«, men desuden af og til udsendt »Meddelelser« navnlig om Undersøgelsesrækker af videnskabelig-teknisk Natur. Disse Meddelelser have handlet om:

»Ingeniøren«

- I. Statsprøveanstaltens 50000 kg. automatiske og autografiske Prøvemaskine fra *Tinius Olsen & Co.*, Philadelphia 1898, Nr. 11, S. 77
- II. Forsøg med Gummipakningsringe med Lærredsindlæg 1899, » 15, » 119
- III. Om Linoleum 1900. » 44, » 339
- IV. Om Prøvning af Klinker mod Slid 1901, » 14, » 73
- V. Undersøgelser vedrørende Restaureringen af Børsen i Kbhvn. 1902, » 8, » 57
- VI. Undersøgelser vedrørende Restaurering af Thorvaldsens Musæums Facade 1903, » 2, » 9

¹⁾ Baumaterialienkunde 1902, S. 313.

- VII. Pyrometriske Undersøgelser af nogle danske Lersorter..... 1903, Nr. 12, S. 89
- VIII. Beretning om de for Dansk Ingeniørforenings Rørudvalg udførte Prøver med Damprør samt Gas- og Vandrør..... 1903, » 42, » 293
- IX. Undersøgelser over Molerets Anvendelighed i Industrien..... 1904, » 24A, » 177
- X. Undersøgelser over Maling paa frisk, overfladetør eller fugtig Cementpuds... 1905, » 28, » 183
- XI. Foreløbig Meddelelse om Statsprøveanstaltens Forsøgsrække vedrørende Trækonserverings-Midler..... 1905, » 45, » 295
- XII. Undersøgelser over Linolie og Rustbeskyttelsesmidler..... 1906, » 1, » 1
- XIII. Om Prøvning af Rør af Ler og Cement 1907, » 29, » 211
- XIV. Undersøgelser over Cementmursten.... 1907, » 46, » 341
- XV. Om Frostprøvning af Kalksandsten ... 1908, » 37, » 299
- XVI. Resultater fra Prøvning af forskellige Materialier: Støbejern, Kæder, Staaltove, Tovværk og Kiselguhr 1909, » 33, » 307

Om mindre Undersøgelsesrækker er der givet Oplysninger i Aarsberetningerne. Enkelte af Undersøgelsesrækkerne have handlet om ny Prøvemetoder og Apparater. Endvidere er der fra den foran nævnte særlige Afdeling af Statsprøveanstalten, Lerlaboratoriet, udgivet en Række af 13 Forsøgsrapporter, som have været offentliggjorte i Nordisk Tidsskrift for Lervare- og Stenindustri (nu Lerindustrien).

I det følgende skal der gives et kort Udtog af nogle af Anstaltens Publikationer.

Statsprøveanstalten i Kbhvn. d. 1ste Aug. 1909.

H. I. HANNOVER.

B. Udtog af Statsprøveanstaltens Publikationer¹⁾.

I. Metalundersøgelser.

Hvad Metalundersøgelser angaar, har Anstalten kun i ringe Grad kunnet foretage Undersøgelsesrækker, da Udgiften ved Tildannelsen af Prøvelegemer vilde blive for stor for de smaa Midler, der have staaet til Raadighed. Kun paa et enkelt Omraade er der foretaget en større Undersøgelsesrække, nemlig angaaende Prøvning af Rør af smedeligt Jærn (Meddelelse VIII), idet Dansk Ingeniørforening ønskede en større Række Prøver udført for at fastslaa hensigtsmæssige Prøvemetoder til Brug for Affattelsen af Leveringsbetingelser for saadanne Rør.

Ved den 4de internationale Kongres i Bryssel i 1906 forelagde Anstaltens Direktør, Prof. *Hannover*, Resultaterne af denne Undersøgelsesrække og de vedtagne danske Leveringsbetingelser, hvortil her maa henvises²⁾.

Det vil maaske have Interesse at se, hvorledes senere — 10: fra Undersøgelsesrækkens Slutning indtil d. 1/1 1909 — prøvede Rør have taalt de foreskrevne Prøver:

Hvad Damprør angaar, er Trækprøve udført for 8 Leverancer, idet Prøven udførtes for ialt 41 Rør. Blandt disse 41 Rør faldt Prøven utilfredsstillende ud for 5 Rørs Vedkommende. For 1 af disse Rørs Vedkommende var det Styrken, der var for ringe, nemlig kun 31,9 kg pr. mm² i Stedet for mindst 33 kg

¹⁾ Udtoget er hist og her suppleret med Enkeltheder, der ikke tidligere have været offentliggjorte.

²⁾ Den tyske Forhandlingsprotokol S. 173.

pr. mm², for 3 var det Forlængelsen, der var for lille, nemlig 9,9, 9,0 og 7,8 % i Stedet for mindst 12 %, og for et Rør var begge Dele for smaa, nemlig henholdsvis 31,5 og 11,7.

For Damprørs Vedkommende er Bøjningsprøve udført for de samme 8 Leverancer, men kun for ialt 34 Rør. Af disse var der kun ét, der ikke bestod Prøven, men revnede paa tværs, nemlig det Rør, hvis Materiales Forlængelse kun var 9 %.

Hvad Gas- og Vandrør angaar, er Trækprøve udført for 5 Leverancer, idet Prøven udførtes for ialt 33 Rør. Blandt disse 33 Rør faldt Prøven utilfredsstillende ud for 6 Rørs Vedkommende.

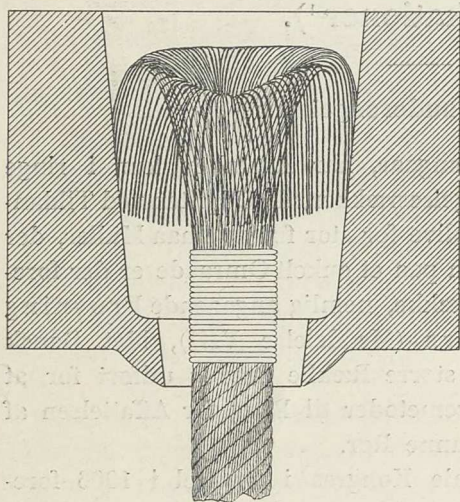


Fig. 7.

For 3 af disse Rørs Vedkommende var Styrken for ringe, nemlig henholdsvis 30,0, 31,3, samt 31,2 à 32,0, i Stedet for mindst 33 kg pr. mm², for 3 andre var det Forlængelsen, der var for lille, nemlig 10,3, 11,8 og 6,8 à 7,9 i Stedet for mindst 12 %. Ved Røret med 30,0 kg pr. mm² Brudstyrke kunde Forlængelsen ikke maales, da Brudstedet faldt udenfor Maalelængden.

For Gas- og Vandrørs Vedkommende er Bøjningsprøve udført for de samme 5 Leverancer, men kun med 31 Rør. Af disse var der 2, som ikke bestode Prøven, det ene revnede paa tværs, nemlig det med Brudstyrke 30 kg pr. mm², ved det andet aabnede Svejsfugen sig stærkt.

Ved Kongressen i København vil Afdelingsingeniør Karsten holde et Foredrag om Prøvning af Rør af smedeligt Jærn og gøre nærmere Rede for Resultaterne af de her nævnte Prøver.

Ved Prøvning af Staaltraadstøve blive Tovets Traade som sædvanlig opviklede og faststøbte. Som det ses i Fig. 7 er den Bøsning, hvori Faststøbningen sker, paa Midten af Undersiden afdrejet efter en Kugleflade, der under Trækprøven hviler mod en tilsvarende Fordybning, saa at der opnaas central Indspænding ved den derved frembragte Kuglebevægelse.

Til Prøvning af Cykel-Forhjulsgafler mod Slag har Anstalten konstrueret det i Fig. 8 viste Apparat.

Forhjulsgafflens Kronerør bliver indspændt saaledes, at Gaffelskederne *G* rage vandret ud og yderst blive belastede, som vist i Figuren, ved Paa-hængning af en Vægt *P*, stor 93 kg, hvorpaa Strømmen til en Elektromagnet *E* bliver brudt, saa at det derunder hængende Anker *A*, der vejer 2,16 kg, falder ned paa *P* gennem en Højde af c. 18 cm.

Ved Prøven bliver det undersøgt, om Gafflerne lide Skade, idet Anstalten har fastslaaet en bestemt Formforandring af Gafflen som den største tilladelige, og indrettet et særligt Maa-leapparat til hurtig Bestemmelse af, om den er overskreden eller ej. Iblandt de indtil d. 1ste Juli 1909 prøvede 370 Gaffler har der været ialt 8 Gaffler, som ikke bestode denne Slag-Bøjningsprøve.

Efter at være underkastet denne Prøve, blive de prøvede Forhjulsgafler underkastede en Trækprøve for at konstatere, om der ved Slagprøven er fremkommet en skjult Revne eller sprunget en Lodning.

I Trækprøveapparatet udøves Trækraften, 500 kg, ved med

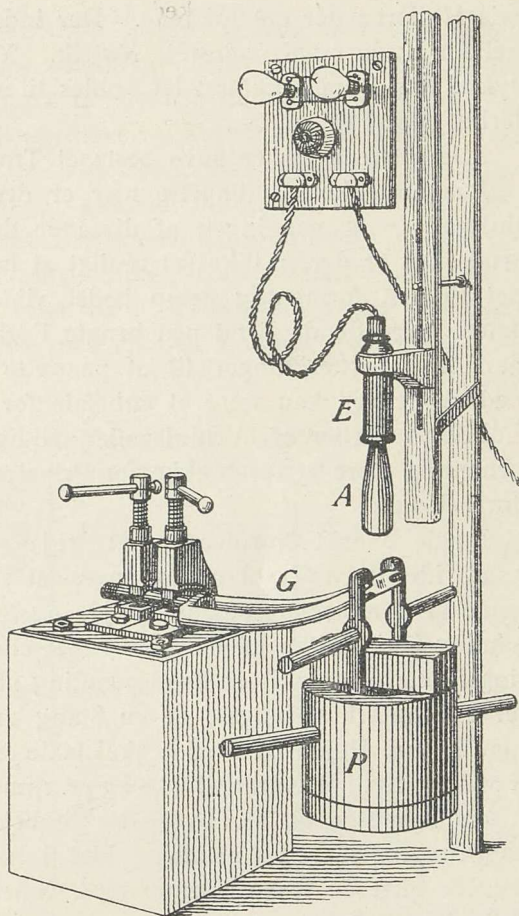


Fig. 8.

en meget lang Vægtstang at dreje en Aksel, hvorpaa der derved opvikles en Kæde. Denne trækker da i en Møtrik paa Forhjulsgaflens Kronerør, idet der bliver holdt igen af et Par i Betongulvet nedstukne Jærnstænger enten imod Gaffelkronen eller i en Tværstang gennem Akselhullerne i Skedernes Ender, nemlig hvis Hullerne dér ere lukkede. Der indskydes et Dynamometer mellem Kæde og Kronerørets Møtrik. Ved et særligt Koblingsstykke kan Dynamometret let kobles til nævnte Møtrik og skilles derfra efter Prøven.

Alle prøvede Gafler have bestaaet Trækprøven.

Paa en enkelt Undtagelse nær er der kun prøvet nye Forhjulsgafler, og paa ingen af disse er der ved Prøven opstaaet Brud. Det er derfor ikke ret muligt at bedømme Prøvens Værdi, idet Prøven formentlig netop bedst vilde egne sig til at konstatere begyndende Brud paa brugte Forhjulsgafler. Iøvrigt har man nu Forstærkninger til at paasætte indeni Kronerøret, og medens Prøven kan være at anbefale for Cykel-Forhandlere ved Indkøb af Partier af Forhjulsgafler, vil Købet af en Forstærkning formentlig være at foretrække for Privatpersoner trods den noget større Udgift.

Da de danske Normer for Støbejern ere forskellige fra de tyske, idet det i Tyskland forlanges, at en Stang med et Fritliggende af 1 meter og 30 mm Højde og Bredde skal taale en Belastning paa Midten af 450 kg, hvilket efter den almindelige Bøjningsformel svarer til en Brudspænding af 25 kg pr. mm², medens der i Danmark forlanges, at en Stang med samme Fritliggende men 25 mm Højde og Bredde skal taale en Belastning paa Midten af 300 kg, hvilket svarer til 28,8 kg pr. mm², kan det maaske have nogen Interesse at se, hvorledes Støbejernsstænger have taalt Bøjningsprøven ved Anstalten, idet i Aarenes Løb 26 Stk. ere prøvede efter de tyske Normer og 29 efter de danske (Anstaltens Meddelelse XVI).

Det viste sig, at de nævnte 26 Forsøg i Middeltal gave en Brudgrænse af 26,7 kg pr. mm², og at 3 af Resultaterne vare under 25 kg pr. mm², medens Middeltallet af de sidste 29 Resultater var 28,8 kg pr. mm², hvoraf 16 Resultater vare under 28,8 kg pr. mm².

Hvad mere specielle Undersøgelser angaar, kan nævnes, at Anstalten har gjort *Brinellske* Haardhedsprøver, *Heynske* Slagbøje-

prøver med indkervede Stænger og allerede i en længere Aarrække har drevet metalmikroskopiske Undersøgelser.

II. Cementundersøgelser.

Anstalten har i Aarenes Løb udført en stor Mængde løbende Undersøgelser, f. Eks. for Vandbygningsvæsenet, der jo bruger Cement i Mængde, navnlig til Kystsikringsarbejderne paa Jyllands Vestkyst, for Stadsingeniøren i København til Københavns nye Kloakanlæg o. s. v., — i de senere Aar ogsaa en Del Cement til Jærnbetonkonstruktioner. Man vil faa en Oversigt over Egenskaberne ved den Cement, der anvendes i Danmark, ved den i Tabel I og II givne Sammenstilling af Resultaterne af Cementundersøgelserne i 1908. Der blev i 1908 afsluttet 167 saadanne Undersøgelser. Alle disse paa én nær bestode Normprøven for Rumfangkonstans.

Tabel I. Resultater af Cementundersøgelser i 1908.

	Størknings- tid	Erdmen- gers Høj- tryks- dampprøve		3 Dage		7 Dage		28 Dage		3 Maaneder	
		Træk	Tryk	Træk	Tryk	Træk	Tryk	Træk	Tryk	Træk	Tryk
Fundne Værdier	7 $\frac{1}{2}$ Timer	26,7	339	13,6	104	19,7	194	25,7	313	31,1	383
Antal Cemen- ter	111	75	73	51	48	64	65	81	79	23	23
De fem højeste Re- sultater laa mellem		37,3 og 43,3	500 og 551	17,7 og 23,5	133 og 191	25,9 og 28,1	296 og 327	32,8 og 35,7	496 og 551	33,7 og 41,0	471 og 591
De fem laveste Re- sultater laa mellem		0—0	0—0	4,1 og 9,2	18 og 70	6,9 og 10,8	46 og 104	13,2 og 17,8	117 og 168	19,7 og 28,3	185 og 283

I Tabel I er gengivet Middeltal af samtlige Resultater (Størkningstid for hurtigt bindende Cemente undtagen) af Størkningsforsøg samt Træk- og Trykforsøg efter 3, 7 og 28 Dages samt 3 Maaneders Forløb fra de i 1908 udførte Cementundersøgelser. Styrketallene ere angivne i kg pr. cm². Desuden er der angivet

i den næste Rubrik, hvor stort et Antal Cements de anførte Værdier ere Middeltal for, og i de følgende Rubrikker de 5 højeste og de 5 laveste Resultater, der i Aarets Løb ere erholdte for de forskellige Træk- og Trykprøver.

I Tabel II er anført Resultater af samtlige Cementundersøgelser i 1908, hvorved der for samme Cementprøve er fundet Styrken baade efter 3, 7 og 28 Dages Forløb og (paa fire nær) efter 3 Maaneders, samt udført Højtryksdampprøve.

Tabel II. Resultater af fuldstændige Cementundersøgelser i 1908.

Størk- ningstid	Erdmengers Høj- tryksdampprøve		3 Dage		7 Dage		28 Dage		3 Maaneders	
	Træk	Tryk	Træk	Tryk	Træk	Tryk	Træk	Tryk	Træk	Tryk
6 ¹ / ₂ Timer	27,5	378	15,0	101	17,9	154	19,8	230	30,2	315
8 —	36,5	430	11,9	92	18,0	183	22,0	286	33,0	364
6 ³ / ₄ —	31,7	445	13,9	104	19,5	190	27,8	339	33,7	414
7 ¹ / ₂ —	33,8	430	14,5	114	23,2	244	35,7	486	35,9	591
7 —	Prøvelegemerne kogte i Stykker		10,6	84	10,8	100	17,5	168	29,6	252
6 —	do.	do.	11,7	88	10,7	104	17,8	162		
5 ¹ / ₂ —	35,7	360	16,0	112	23,1	204	25,1	327		
7 ¹ / ₄ —	36,2	459	18,2	114	21,4	187	27,0	296	31,1	369
7 ³ / ₄ —	33,2	427	16,0	114	20,1	186	28,3	294	29,9	382
6 ¹ / ₄ —	36,2	470	16,4	131	20,7	209	27,0	318	31,0	398
7 ¹ / ₂ —	27,9	379	14,2	126	16,6	127	23,8	226	28,0	324
3 Minutter	17,9	165	9,6	60	10,0	70	13,2	117	19,7	185
6 ³ / ₄ Timer	35,4	500	16,1	127	22,4	212	27,7	352	33,4	466
8 —	35,6	500	15,6	115	23,1	266	31,8	431	32,0	497
6 —	10,3	123	11,3	88	16,6	171	25,6	319		
6 ¹ / ₂ —	35,6	484	17,7	148	21,5	277	28,8	377	31,5	448
8 ¹ / ₂ —	Prøvelegemerne kogte i Stykker		13,6	114	17,4	162	21,0	210		
8 —	27,3	349	13,3	93	15,1	131	23,1	206	28,1	269
6 ³ / ₄ —	35,4	480	16,9	133	21,0	206	26,4	333	36,1	471
7 ¹ / ₂ —	23,9	198	16,2	106	18,7	206	24,9	318	30,5	401
11 —	23,6	314	4,2	41	6,9	68	17,8	158	25,5	234
7 ³ / ₄ —	27,1	362	16,7	116	19,1	157	22,9	221	29,2	302
7 ³ / ₄ —	40,1	478	17,7	145	28,1	284	33,8	497	41,0	569
7 —	43,3	551	23,5	191	28,0	286	34,0	505	36,4	532
7 —	37,3	473	16,1	111	21,2	202	26,1	318	32,7	413
6 ¹ / ₄ —	Prøvelegemerne kogte i Stykker		12,3	96	13,8	135	16,8	209	28,3	283
ca. 45 Minut.	27,1	303	9,6	52	13,6	115	20,5	209	28,7	332

Den i ovenstaaende Tabeller anførte Erdmengerske Højtryksdampprøve består i, at der af Cementen paa sædvanlig Maade formes Træk- og Trykprøvelegemer, og at disse efter 24 Timers Henstand i fugtig Luft, henlægges i Vand i yderligere 2

Døgn og derpaa koges i en lille Dampkedel ved 10 Atm. Spænding i 6 Timer og træk- eller trykprøves. Til Sammenligning foretages som Regel ogsaa 3 Dages Prøver for Træk og Tryk

Tabel III. Sammenstilling af samtlige Resultater indtil den 1. Jan. 1907 for Cementer, for hvilke der er udført baade 3 Dages Prøve, Erdmengers Højtryksdampprøve og Le Chateliers Prøve.

3 Dage		Erdmengers Højtryksdampprøve		Le Chateliers Prøve	3 Dage		Erdmengers Højtryksdampprøve		Le Chateliers Prøve	3 Dage		Erdmengers Højtryksdampprøve		Le Chateliers Prøve
Træk	Tryk	Træk	Tryk		Træk	Tryk	Træk	Tryk		Træk	Tryk	Træk	Tryk	
11,6	65	9,1	32	9,8	—	77	—	170	1,8	7,5	42	25,2	279	3,0
10,3	73	—	c.37	5,5	—	—	24,4	172	3,0	9,2	58	19,3	280	2,3
15,1	75	11,0	52	9,3	9,0	46	24,4	177	8,5	14,2	74	29,6	281	0,8
12,1	71	10,8	58	10,3	10,6	80	21,5	179	1,8	9,7	68	27,0	286	1,0
11,9	66	8,3	59	10,8	10,6	43	20,4	181	2,5	12,9	105	25,6	286	4,5
17,2	125	6,3	67	10,0	12,9	74	20,4	188	2,5	16,0	106	27,4	292	0,8
6,2	39	9,1	67	14,0	12,8	74	26,2	189	2,5	12,5	92	29,3	294	0,8
13,2	119	6,6	76	4,0	12,2	61	24,5	193	1,3	11,5	63	25,5	297	2,5
7,6	52	5,9	80	19,0	12,2	118	15,6	195	5,5	12,3	77	26,7	298	2,3
11,4	113	6,0	81	4,8	8,0	49	21,2	199	2,0	13,5	126	33,7	309	2,0
11,2	65	13,8	86	6,5	13,5	73	26,8	202	2,8	13,2	107	29,1	316	2,5
13,4	79	16,9	88	5,5	12,7	51	24,4	203	1,5	13,4	112	28,1	330	2,0
—	71	—	89	22,2	8,1	35	23,9	203	1,0	13,8	101	28,7	331	1,8
14,6	80	16,1	92	3,8	3,2	41	24,9	204	1,5	14,0	79	29,7	371	6,5
8,1	62	11,6	96	9,0	12,2	71	24,3	218	6,0	12,1	66	35,0	377	1,3
9,5	58	19,0	97	3,0	9,3	44	30,3	219	2,8	14,9	123	30,2	391	2,0
13,9	84	12,3	100	5,8	11,5	63	23,8	225	2,5	15,1	110	40,7	391	0,5
8,9	76	28,4	100	1,8	9,4	73	28,8	227	1,8	12,2	114	29,2	399	3,3
11,8	97	32,6	103	3,0	11,6	41	23,9	227	0,8	12,7	94	30,5	400	2,3
10,1	97	8,5	110	12,8	10,4	65	28,0	229	2,3	12,8	94	36,8	404	2,0
13,9	140	13,7	127	7,8	10,0	66	26,7	236	2,0	15,3	117	30,6	420	1,3
—	80	—	130	2,5	12,6	71	23,2	241	1,0	11,0	75	30,5	424	1,5
14,6	85	28,3	140	4,0	10,4	63	21,7	243	1,8	12,8	98	31,0	425	2,0
11,5	62	24,2	143	1,5	8,2	46	25,5	244	1,3	9,6	58	33,0	427	1,3
13,6	74	16,5	153	6,3	10,5	84	25,7	245	2,0	14,0	121	32,3	433	1,5
17,0	96	27,6	154	4,3	8,0	59	23,7	248	1,8	10,3	114	26,2	434	1,8
11,6	82	17,0	154	5,0	16,8	84	26,6	250	2,3	15,9	98	31,4	438	3,5
6,6	23	19,8	156	1,3	11,8	82	27,0	257	2,5	12,1	95	29,2	441	1,3
—	71	—	160	3,3	12,4	78	25,0	262	2,3	17,7	133	31,9	460	1,3
15,7	115	13,8	161	3,0	11,8	84	22,9	265	1,3	14,2	101	38,0	483	1,8
11,3	110	14,2	162	6,8	8,5	62	24,0	266	1,3	12,0	110	41,1	502	1,8
11,9	80	22,1	165	8,5	13,5	66	25,3	277	2,0					

udførte paa sædvanlig Maade. Prøven, som er opfundet af Dr. Erdmenger i Hannover, er en fremskyndet Prøve for Rumfangskonstans, som saa vidt vides nu ikke mere bruges andetsteds, men i Danmark i ret stor Udstrækning. Saaledes forlanges den

efter Vandbygningsvæsenets Leveringsbetingelser. Da Anstalten ogsaa har gjort en stor Del fremskyndede Prøver efter *Le Chateliers* Metode, skal der her gives en Sammenstilling af Resultaterne for de to Metoder for de Cementer, for hvilke begge Prøver have været gjort indtil 1. Januar 1907, se Tabel III.

Da Sammenstillingen synes at vise, at Resultaterne af *Erd-*

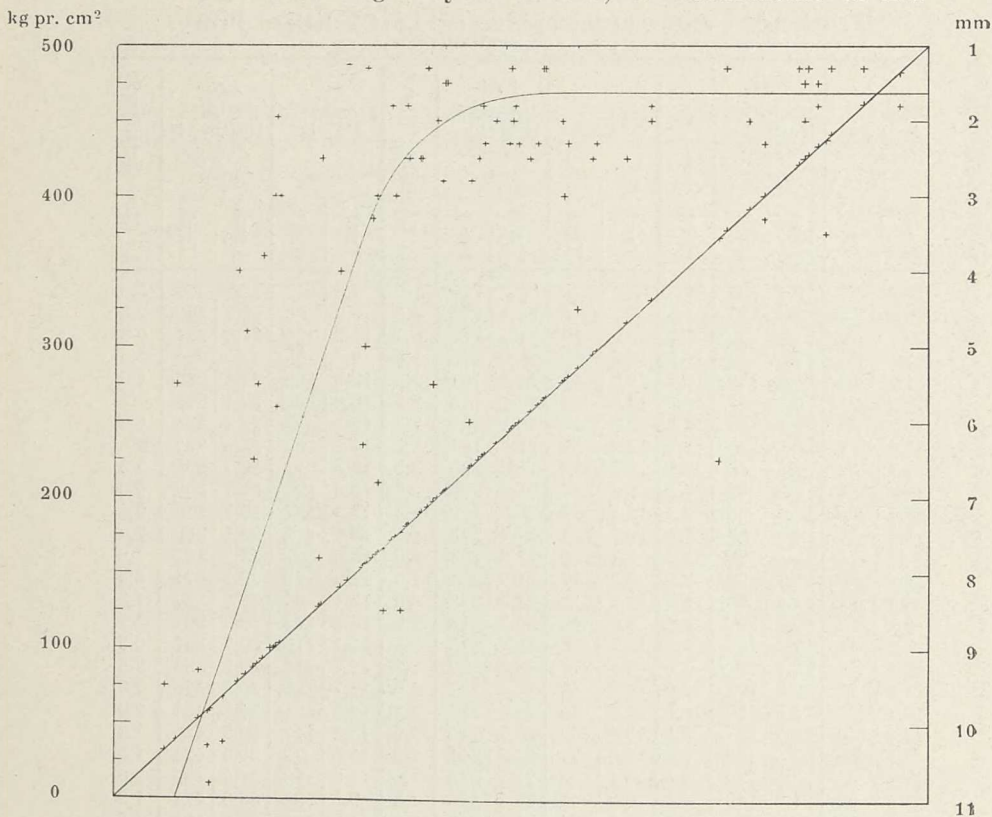


Fig. 9.

mengers Højtryksdampprøve og *Le Chateliers* Prøve ere særdeles afvigende, er der i Fig. 9 for at faa et Overblik givet en grafisk Sammenstilling af dem. Resultaterne af førstnævnte Prøve ere anførte ved paa den skraa, rette Linie at sætte et Hak for hver Prøve, nemlig paa det Punkt af Linien, hvis Ordinater, regnet efter Angivelserne ved Figurens venstre Side, repræsenterer Trykstyrken efter Prøven. For hver Prøve er der paa samme Ordinat med et Kryds mærket Resultatet af *Le Chateliers* Prøve, idet den

fundne Forøgelse af Afstanden mellem Naalene er afsat fra oven nedad efter Angivelsen ved Figurens højre Side. 4 Resultater, hvor Afstanden mellem Naalene var under 1 mm eller over 11 mm, ere udeladte. Paa Skøn er der dernæst lagt en Kurve, som repræsenterer Beliggenheden af nævnte Krydser. Det ses, at denne Kurve øverst har en vandret Del, som viser, at *Le Chateliers* Prøve som Regel kun giver Udslag paa indtil ca. 3 mm mellem Naalespidserne, saa længe man ved *Erdmengers* Kogeprøve faar en Knusningsstyrke paa over ca. 200 kg. Men naar Styrken efter sidstnævnte Prøve falder derunder, vokse Udslagene ved *Le Chatelier*-Prøven stærkt, hvilket viser sig ved, at Kurven gaar over i en brat nedadgaende Gren.

Anstalten har gjort en Del Forsøg med Feretske Cementprismer til Sammenligning med de almindelige Normprøver, navnlig gaaende ud paa at bestemme den Indflydelse, som forskellig Vandtilsætning og forskellig stærk Stampning af Prismerne har paa Styrken. En Beretning om en Del af disse Forsøg er indsendt til Prof. *Schüle* i Zürich som Formand for Kommission 42.

Anstaltens fungerende Underdirektør, Hr. *Mayntz Petersen*, har allerede før Brüsseler-Kongressen gjort en Del Forsøg for Kommission 30 til Bestemmelse af Mængden af fint Støv i Cement, se Prof. *Garys* Beretning til Brüsseler-Kongressen, Forsøgene, der ere udførte for den skandinaviske Portlandcementfabrikantforening ere senere blevne afsluttede, og Beretning er derefter afgiven til Prof. *Gary* til Brug for hans Foredrag ved Kongressen i København.

Den samme Forening har allerede i 1896 ved Anstaltens Hjælp paabegyndt en Række Forsøg over Cementmørtels Modstandsdygtighed mod Havvandets Indflydelse, hvortil der af Anstalten blev fremstillet 4000 Tærninger, som bleve nedsatte forskellige Steder i de nordiske Have. Paa nævnte Forenings Vegne vil Afdelingsingeniør ved Vandbygningsvæsenet A. *Poulsen* i Lemvig aflægge en Beretning paa Kongressen i København om de hidtidige Resultater.

Ved Brysseler-Kongressen blev det vedtaget, at Prøven for Normalkonsistens skulde gøres i en indvendig konisk Form paa nærmere angiven Maade med 400 g Cement. Ved Anstaltens Forsøg har det imidlertid vist sig, at denne Cementmængde er

vel lille, hvilket er bekræftet ved Forsøg af Prof. *Mesnager*, hvorfor Anstalten ved fungerende Underdirektør *Mayntz Petersen* agter at bringe Spørgsmaalet om en Ændring af de i Bryssel vedtagne Regler paa dette Punkt frem ved Kongressen i København.

Ved Anstalten er der gjort forskellige andre Undersøgelser over Cement, f. Eks. over Cementmørtels Evne til at beskytte Jærnkonstruktioner mod Brand. Nogle andre for Ingeniørkaptajn *Grut* udførte Forsøg over Cements Styrke ved højere Temperaturer, har han offentliggjort i den tekn. Forenings Tidsskrift, 1903—4, Bd. 27, S. 206.

Angaaende nogle Undersøgelser over Cementpuds, se III f.

III. Andre Undersøgelser.

a. Prøvning af naturlige Sten.

Anstalten har selvfølgelig udført de almindelige Undersøgelser over naturlige Stens Styrke mod Tryk, Vandsugningevne, Frostbestandighed, Modstand mod Slid o. s. v.

Modstanden mod Slid er bestemt paa den S. 21 nævnte Dorryske Slidprøvemaskine, hvorpaa saa vel Tabet i Vægt som i Højde bestemmes. I den følgende Tabel IV er sammenstillet Anstaltens Resultater indtil 1. Januar 1909 for Slidprøver af baade naturlige og kunstige Sten.

Som Eksempel paa en større Undersøgelsesrække vedrørende naturlige Sten kan nævnes Undersøgelser, som foretoges for 8 Aar siden i Anledning af Restaureringen af Børsen i København.

Det viste sig nemlig, at en 20 Aar tidligere foretagen Restaurering, der havde kostet ca. 100,000 Kr. for Stenarbejdets Vedkommende, kun havde været af kortvarig Nytte, idet der af de i gullandske Sandsten udhuggede Figurer paa Bygningen faldt store Stykker af. Anstaltens Undersøgelser gik bl. a. ud paa at udfinde, hvilken Virkning det vilde have at fluatere den gullandske Sandsten saavel med Hensyn til dens Modstand mod Frost som mod Slid, og paa at sammenligne ny, gullandsk Sandsten og gammel do. fra Børsen i saa vel ufluateret som fluateret Tilstand med Sandsten fra Obernkirchen i Hessen-Cassel (her i Danmark kaldt Bremersandsten) med Hensyn til Vejrbestandighed, nemlig ved den af Prof.

Seipp angivne Prøve¹⁾. Et Udtog af Anstaltens Meddelelse V angaaende denne Undersøgelsesrække har været optaget i »Baumate-

Tabel IV. Slidprøver med Klinker, Betonfliser og andre Stenmaterialier.

Højdetab i mm	Ler- varer		Betonfliser og Cementfliser	Granit og Gnejs	Marmor	Kalksten	Asfalt	Flint	
	Klinker	Fliser							
indtil 1 mm	1	2	12	16				12	
fra 1,1—2 —	30	4	43	3			2	2	
- 2,1—3 —	19	6	19				12		
- 3,1—4 —	6	4	7		1	2	7		
- 4,1—5 —	13	6	4		1		4		
- 5,1—6 —	7	5	2		1		1		
- 6,1—10 —	12	7							
- 10,1—16 —	5	3			1				
- 16,1—20 —		3							
Antal Sorter	93	40	87	19	4	2	26	14	ialt 285

**Vægttab
i g pr. cm² Slidflade**

fra 0,1 —0,2 g	4	3	7	9				16	
- 0,21—0,3 -	6	2	20	10			1		
- 0,31—0,4 -	14	1	15						
- 0,41—0,5 -	16		19				4		
- 0,51—1 -	25	13	25		1	2	19		
- 1,1—2 -	22	2	1		2		2		
- 2,1—3 -	6	9			1				
- 3,1—4 -		3							
- 4,1—5 -		4							
- 5,1—6 -		1							
- 6,1—7 -		1							
- 7,1—8 -		1							
Antal Sorter	93	40	87	19	4	2	26	16	ialt 287

Højdetabet er ikke opført for to Flintstenssorter.

rialienkunde» 1902, S. 218. Det skal heraf anføres, at Fluatering beskyttede gullandsk Sandsten noget mod Frost og Slid, men at der

¹⁾ Prof. Seipp: Die Wetterbeständigkeit der natürlichen Bausteine und die Wetterbeständigkeitsproben, Jena 1900, S. 176.

ikke var stor Forskel paa, hvorledes de fluaterede og ufluaterede, gullandske Sandsten stode sig mod *Seipps* Vejrbestandighedsprøve, hvorimod Bremersandstenene stode sig langt bedre end begge. Ved Bygningens senere Restaurering blev der anvendt Fluatering i stor Maalestok til de Sten, der kunde restaureres, hvorimod der blev anvendt Bremersandsten, hvor Udveksling var nødvendig. Efter foretagne Undersøgelser kunde Anstalten til Rensning før Fluateringen anbefale at udføre denne med Jærntraads-Kradsbørster saa grundigt som muligt, idet der, naar man fluaterede paa Dele, der ikke vare rensede ordentlig, og herefter vilde rense videre, var Fare for, at Rensningen med Kradsbørsterne vilde afsætte saa meget Jærn paa de nu haarde Sten, at man bagefter fik Rustpletter ved Fluateringen.

b. Prøvning af brændte Sten og Undersøgelser af Raamaterialier dertil.

Hvad Prøvning af disse Sten angaar, som siden Oprettelsen af Anstaltens foran nævnte Lerlaboratorium ere foregaaede paa dette, er der anvendt de almindelige Metoder for Undersøgelse af deres Styrke mod Knusning, Vandsugningsevne, Frostbestandighed, Indhold af opløselige Salte, Indhold af skadelige Smaasten, Adhæsion til Mørtel o. A., desuden særlig undersøgt Klinker for Slid¹⁾, Tagsten for Gennemtrængelighed, Glaserede Varer for Glasurens Vejrbestandighed, Ildfaste Sten for Ildfasthed, Rumfangskonstans under Brændingen, Modstand mod Temperaturveksling etc.

Som særlige Undersøgelser vedrørende brændte Sten kan anføres følgende, der omhandles i nogle af de af Statsprøveanstaltens Lerlaboratorium udgivne 13 Forsøgsrapporter, nemlig:

1. Sammenlignende Adhæsionsforsøg mellem Molersten og alm. Mursten.
2. Udtørningsforsøg med Molersten, alm. gule Sten og Klinker.
4. Sammenlignende Styrkeprøver mellem Sten brændte paa Teglværk og Laboratorieprøver.
5. Glasering paa kalkholdig Skærv.
8. Imprægnering og Farvning af Skærven i gule Tagsten.

¹⁾ Herom var der allerede inden Lerlaboratoriets Oprettelse udgivet Meddelelse IV.

9. Imprægnering af røde Tagsten med Centrifugemælk.
10. Imprægnering af røde Tagsten med Vandglas.
11. Sammenlignende Undersøgelser mellem Cementmursten og alm. Mursten.

Lerlaboratoriet har naturligvis i udstrakt Grad befattet sig med Undersøgelser af Ler og andre Raastoffers Anvendelighed til Fremstilling af brændte Sten.

Den første større Undersøgelse af denne Art omhandlede: Pyrometriske Undersøgelser af nogle danske Lersorter (Anstaltens Meddelelse VII).

For at kunne foretage disse Undersøgelser med tilstrækkelig Nøjagtighed, blev det nødvendigt at forskafe sig en Ovn, ved hvilken man ikke alene kunde naa den tilstrækkelige Temperatur, men ogsaa kunde regulere denne, navnlig holde den konstant i længere Tid. Da dette viste sig meget vanskeligt med de forhaandenværende Gasovne, bestemte man sig til at konstruere en elektrisk Ovn.

Ved nogle tidligere for Statsprøveanstalten udførte Forsøg havde cand. mag. nu Prof. ved polyt. Lærestalt *Absalon Larsen* i andet Øjemed som elektrisk Ovn benyttet en udvendig skrueskaaren Chamotte-Cylinder med en i Skruegængerne indlagt Nikkeltraadsbevikling, der gennemstrømmedes af Elektricitet. Da Anstalten endnu var i Besiddelse af denne Cylinder, besluttedes det at benytte den til selve Ovnkammeret i den nye, elektriske Ovn.

Ved de omtalte Forsøg var man imidlertid kun gaaet op til Temperaturer omkring 1000° C., hvorfor det bestemtes først at se, hvor højt man kunde naa, naar Cylinderen isoleredes godt.

Cylinderen bevikledes derefter med en dobbelt Nikkeltraad; den enkelte Traads Diameter var 1 mm. Den beviklede Cylinder sættes ned i en Sumpbrønd af saltglaseret Ler, hvor der i Bunden laa et Lag Sand, derpaa Asbestfnug og sluttelig et Lag Kaolin. Dernæst anbragtes udenom Cylinderen et Lag Kaolin, som ved en Asbestcylinder var adskilt fra et ydre Lag af Asbestfnug. Temperaturen iagttoges med le Chateliers Pyrometer, hvis Loddested anbragtes i Midten af Chamottecylinderen. Foroven lukkedes Cylinderen med en Chamotteprop med et Hul i Midten, hvorigennem Pyrometret kunde stikkes ned.

Ved en Temperatur af ca. 1400° C., der naaedes efter ca. 2 Timers Forløb, brændte Traaden over, men af den over Tempe-

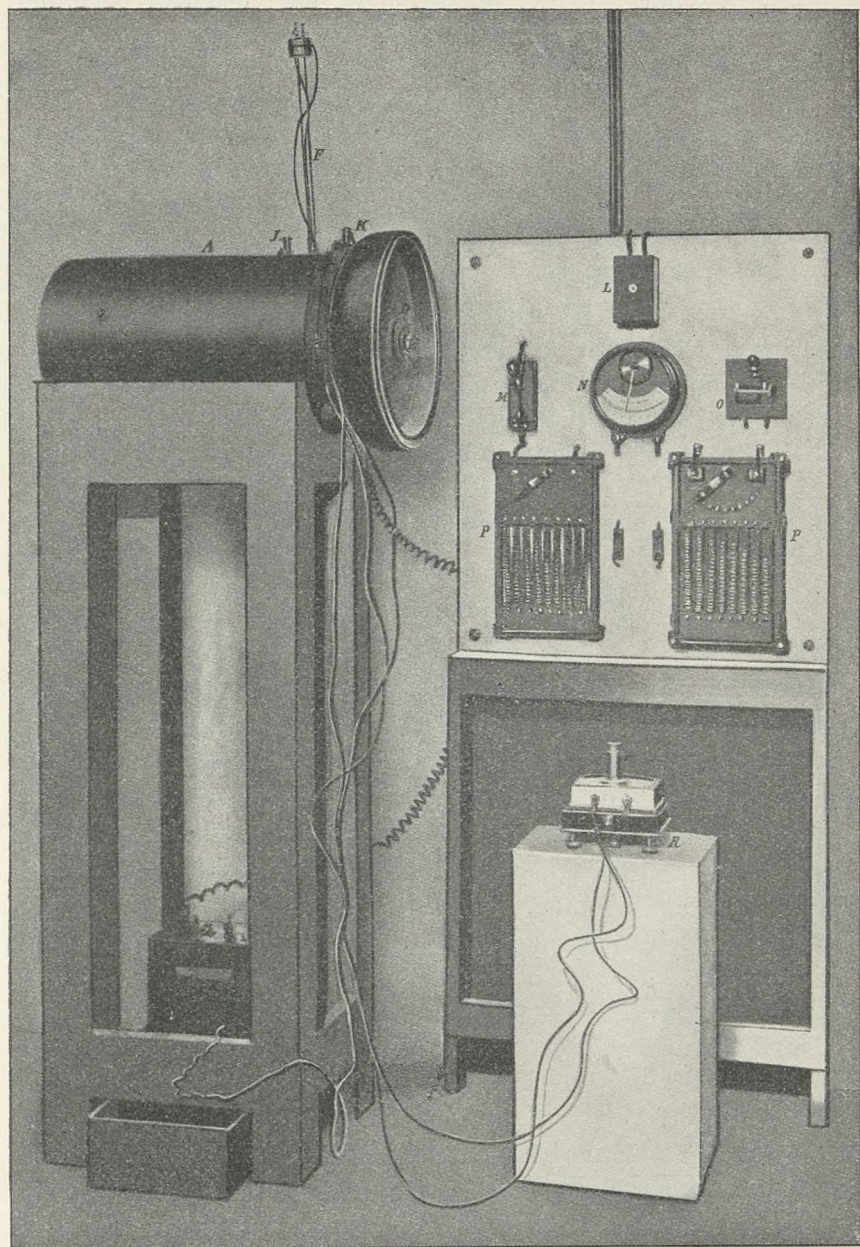


Fig. 11.

Det bestemtes ved det første Forsøg med den nye Bevikling at prøve at naa 1500° C. og tillige at iagttage, hvor hurtigt man kunde naa dette Punkt.

Det viste sig, at man kunde naa denne Temperatur i Løbet af ca. $1\frac{1}{2}$ Time.

Der blev nu indlagt en særlig Ledning til Ovnén og opsat en Fordelingstavle med en énpolet Afbryder, et Ampèremeter, en automatisk Strømafbryder, som bryder ved 17 Ampère, 2 Traadrheostater paa henholdsvis 2 og 10 Ohm samt de fornødne Polklemmer og Sikringer. Hertil kom noget senere, dels da Strømreguleringen ikke var saa fuldstændig, som ønskeligt var, og dels fordi Begyndelsesstrømmen var lovlig stærk, en Vandmodstand, bestaaende af et Glaskar med 2 Akkumulatorplader i.

Fig. 11 viser Ovnén med Fordelingstavle m. m. L er Sikringer, M Afbryder, N Ampèremeter, O automatisk Afbryder, P Traadrheostater, Q Vandmodstand og R et Millivoltmeter til Pyrometret.

Denne Ovn har i det hele taget ikke skuffet de Forventninger, der knyttedes til den. Den er ganske overordentlig let at regulere. Man kan saaledes i Timevis holde Temperaturen konstant, maaske svingende 5° ud fra Ligevægtstillingen.

Man kan som før nævnt udmærket godt bruge Ovnén ved Temperaturer op til 1500° . Anstalten er dog gaaet over til kun at anvende den ved Temperaturer indtil 1400° , hvilket har vist sig at være heldigt for Forlængelsen af Platinbeviklingens Funktionstid. Ved nogle Forsøg, hvor Temperaturen blev konstant ved ca. 1500° i et Par Timer, viste det sig, at en ganske ny Platinbevikling brændte over efter et ganske ringe Antal Brændinger. Hvis man derimod kun benytter den ved Temperaturer under 1400° , kan man nok gøre Regning paa, at en Platinbevikling kan holde til 700—800 Brændetimer.

Med ovennævnte Ovn er der bl. a. udført en større Forsøgsrække over Fremstilling af Klinkerblandinger (Anstaltens Meddelelse VIII).

Blandt Lerlaboratoriets Forsøgsrækker vedrørende Undersøgelser af Raastoffer til Fremstilling af brændte Sten kan fremhæves dets Undersøgelser over Molerets Anvendelighed i Bygningsvæsenet og i Industrien (Anstaltens Meddelelse IX). »Moler« er et Lokalnavn for den eocène, lerholdige, skifrede Diatomékisel, der findes forskellige Steder i Jylland og navnlig

i den nordlige Del af Mors, paa Fur o. a. Steder ved Limfjorden's Kyster, saaledes ved Silstrup og i Erthølle Hoved. Der har flere Gange været gjort Forsøg paa at udnytte Moleret, uden at der dog er kommet noget videre ud deraf.

Statsprøveanstalten kom ind paa at eksperimentere med Moler som Bygningsmateriale derved, at nuværende Direktør for den polyt. Lærestalt *G. A. Hagemann* foreslog den at forsøge Fremstilling af Kalksandsten ved at blande Kalk, Moler og Sand. Det viste sig imidlertid, at Moleret ikke egnede sig hertil.

Statsprøveanstaltens Lerlaboratorium slog nu ind paa at forsøge Fremstilling af brændte Sten ved Blanding af Ler og Moler i forskellige Forhold. Der blandedes saaledes Moler med 25, 50 og 75 % Mergel samt med 25 og 50 % Rødler; desuden prøvede man at brænde Sten af Moler alene. Det viste sig ved Brændingen, at man mod Forventning af Moleret alene fik en smuk rød Sten, meget fast og let; man kunde slaa et Søm i en saadan Sten, uden at den revnede.

Efter dette Resultat gjordes alle senere Forsøg med ublandet Moler.

Da det havde vist sig, at man af Moleret kunde fremstille meget lette Sten (Vægtf. c. 1), der dog vare lige saa stærke som almindelige Mursten, henvendte Bestyrelsen for Lerlaboratoriet, der som før nævnt skylder Skrikes Stiftelse sin Oprettelse, sig nu til Stiftelsen med Forslag om at bevilge 1000 Kr. dels til fortsatte Forsøg, dels til at søge erhvervet Afgravningsret til et Molerleje med vel egnet Moler og med gode Udskibningsforhold. Hensigten hermed var dels at hindre, at Fabrikationen skulde blive paabegyndt med mindre vel egnet Moler og mulig derved bringe Molersten i Vanry, dels at hindre, at eventuel Fordel ved en lønnende Fabrikation, paa Basis af Lerlaboratoriets Undersøgelser, med Urette skulde tilfalde Spekulanter eller paagældende Lodsejere.

Lerlaboratoriets Ingeniør, Hr. *Fischer-Møller*, berejste i den Anledning dels sammen med Kapt. *Loof*, Hobro, og dels sammen med Statsgeolog Dr. phil. *V. Madsen* gentagne Gange Molerterrænet. Ved disse Rejser lykkedes det at finde et særlig velegnet Molerleje ved Ejerslev pr. Mors.

Fig. 12 viser et Parti af Ejerslev. Klinten er paa det paagældende Sted 16—20 m høj. Tilhøjre paa Billedet ses tydeligt

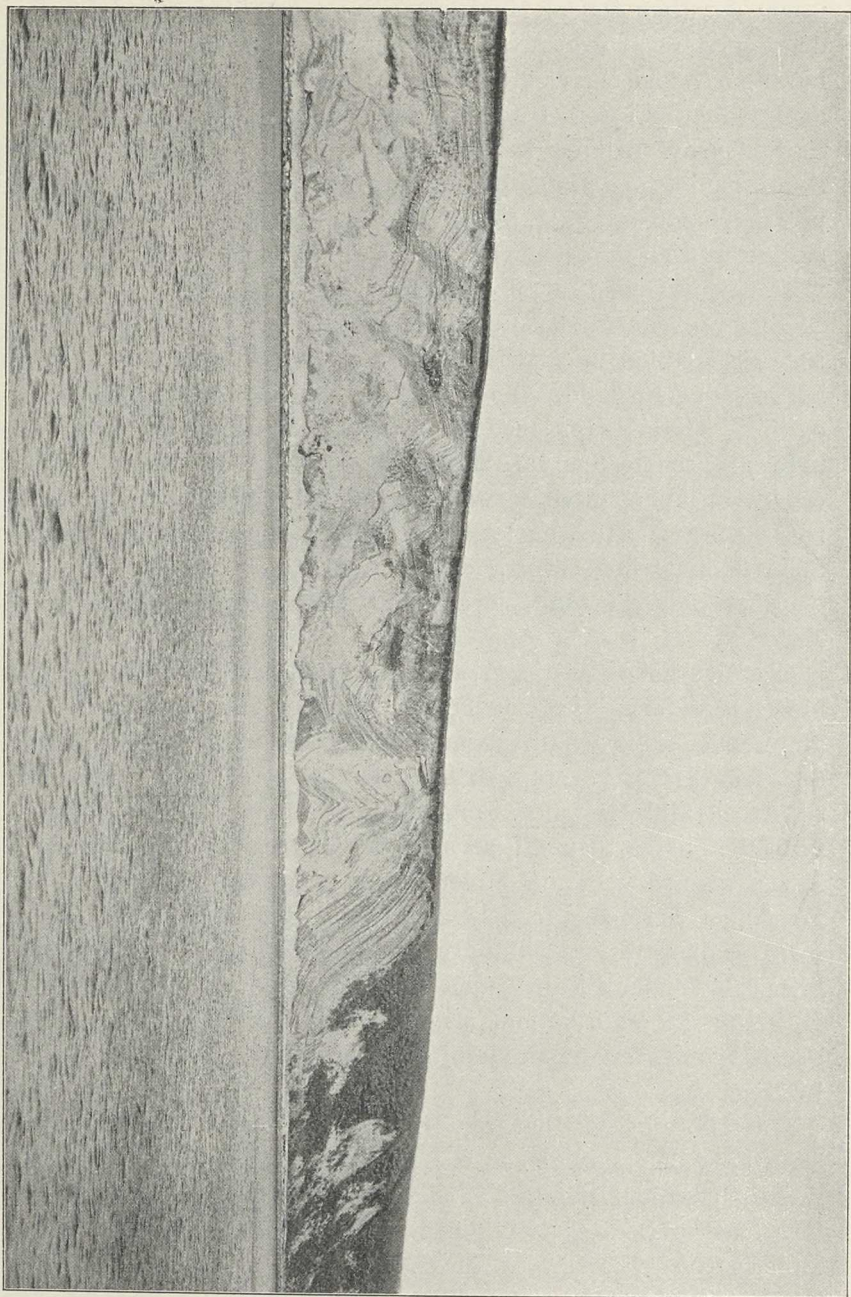


Fig. 12. Parti fra Ejerslev. Efter Fotografi tilhørende Danmarks geologiske Undersøgelse.

stærke Forkastninger og Foldninger. De mørke Striber hidrøre fra Lag af sort, vulkansk Aske, der altid ledsager Moleret. Hvor disse Askelag optræde i stor Mængde og Tæthed, gøre de Moleret ganske uanvendeligt til Fremstilling af lette Sten.

Da Statsprøveanstaltens Forsøg i det smaa lod formode, at der ved Udnyttning af Molerlejerne ved Ejerslev kunde blive Tale om en ny, dansk Industri, maatte det næste Skridt være at forsøge en Fabrikation paa et Teglværk, og en saaaan paa-tog Kaptajn *Loof* sig velvillig at udføre paa det ham tilhørende Vindø Teglværk ved Hobro. De efter adskillige, praktiske Vanskeligheder med Hensyn til Formning, Tørring og Brænding fremstillede Sten bleve nu undersøgte paa Statsprøveanstalten og viste, alt efter Brændingsgraden og Behandlingen, en Styrke mod Tryk af fra 86 til 230 kg pr. cm². Vægtfylden laa mellem 0,87 og 1,13, hvilket sidste Tal gjaldt de haardest brændte Sten. Vandsugningsevnen var i alle Tilfælde betydelig og kunde andrage over 50 %.

Det mærkeligste var uden Tvivl Molerstenenes store Styrke i Forhold til Letheden og i Forhold til andre i Handelen gaaende, lette Sten. Saaledes vise f. Eks. rhinske Svømmesten kun en Trykstyrke af 18—29 kg pr. cm².

Af særlige Anvendelser for Molersten kan nævnes Benyttelse til Skillerum, der mures direkte paa Etageadskillelsen uden andet Underlag end denne, samt til Etageadskillelser og til Hvælvinger af enhver Form. Hvor man bruger dem til Hvælvinger mellem Jærnbjælker, ville Jærnbjælkerne kunne gøres svagere end ved Anvendelsen af almindelige Mursten. Da Stenene kunne gøres sømfaste, kunne de ligesom Svømmesten anvendes ved Befæstelse af Dørkarme. Paa Vindø Teglværk blev der fremstillet særlige Sten til deraf at mure Kakkélovnspladser i Flugt med Bræddeskillerum. Paa Grund af Molerstenenes Lethed er det muligt at anvende Sten af dobbelt Højde, uden at de blive tungere end almindelige Mursten. Herved blive Fugernes Antal mindre, der bruges mindre Kalk, og Stabling, Læsning samt Af-læsning bliver nemmere. At Molersten af almindelig Størrelse ville være særdeles behagelige for Murere og Arbejdsmænd at haandtere, samt at de ville kunne lastes i dobbelt Antal paa Jærnbanevogne og i Pramme, siger sig selv.

Foruden til Skillerumssten kunne Molersten anvendes ved Kedelindmuring, dog ikke istedetfor ildfaste Sten, ejheller til Ydersten, paa Grund af deres stærkt vandsugende Egenskaber. (Af samme Grund egner de sig heller ikke til Understen i Bygninger). Derimod ville de, paa Grund af deres ringe Varmeledningsevne, egne sig godt paa andre Steder ved Kedlers Indmuring. Den ringe Varmeledningsevne er konstateret ved forskellige Forsøg, dels paa Statsprøveanstalten, dels paa Østre Gasværk, hvor Hr. Driftsbestyrer *Irminger* anbragte nogle Sten som Overdækning af Ovnbænken over en Retort og sammenlignede dem med 2 forskellige Slags ildfaste Sten og almindelige Mursten. Paa den nye Fattiggaard »Sundholm« i Kbhvn. har Stadsingeniøren ladet ganske ens Kedler indmure dels med, dels uden Molersten, saa at det ogsaa der ved Forsøg vil blive fastslaaet, om Molersten egne sig godt til Varveisolering. Der foreligger iøvrigt fra anden kompetent Side skriftlig en stærkt anbefalende Udtalelse for, at Molersten paa Grund af deres varveisolerende Evne har vist sig fortrinlige ved Anvendelse til Kedelindmuring¹⁾.

Molerstenens varveisolerende Evne skyldes naturligvis de mange, smaa Lufthuller, som findes i og mellem Kiselalge-Skeletterne. Molerstenene ville af denne Grund egne sig godt som Bagmuringsssten i Ydermure, hvor man ønsker sit Hus lunt. I hule Ydermure ville de rimeligvis egne sig fortrinligt til den indvendige Del af Muren. Ligeledes ville de jo paa Grund af den samme Egenskab egne sig godt som Hvælvingsssten samt til Beklædning af Søjler og Bjælker i Jærnkonstruktioner. Særligt maa det ligeledes anbefales at prøve dem i Murene til Ishuse, Kølerum samt Mejerilokaler og Ostekamre. Endvidere kunne disse Sten anvendes til Filtreersten samt til Hvæssesten.

Paa et enkelt, meget vigtigt Punkt trængte Molerstenene imidlertid til Undersøgelse. Man vidste ikke, hvorledes Stenene vilde kunne modstaa den stærke Ophedning ved en Ildebrand, og med Hensyn til deres Værdi som Bygningsmateriale var det selvfølgelig af stor Vigtighed at komme til Klarhed i denne Henseende. Man havde Erfaring for Stenenes ikke ringe Svind ved deres egen Brænding.

Dette Forhold blev da oplyst, idet Anstalten i 1907 foretog nogle Forsøg for Aktieselskabet Frederiksholms Teglværker, som nedenstaaende gengives.

¹⁾ Anstaltens Aarsberetning for 1907, S. 6.

»Resultat af Brandforsøg med een Steens Mur af Molersten udført efter Rekvisition af Aktieselskabet Frederiksholms Tegl- og Kalkværker.

Der ønskedes undersøgt, om en een Stens Mur kunde modstaa Virkningen af en Ildebrand, uden at Murens Bæreevne opførte, ved at de enkelte Sten sintrede eller smeltede.

Paa Østre Gasværks Terræn opmuredes et Forsøgshus, hvis Konstruktion fremgaar af hosstaaende Fotografier. Forsøgshuset havde en Højde af 157 cm og var opmuret af een Stens Mur. Den midterste Tværmur blev opført af Molersten, nemlig 6" brede Skillerumsten, indsendte af Akts. Frederiksholms Tegl- og Kalkværker. Disse Sten bleve murede med Bredden vinkelret paa Murens Tykkelse og i Forbandt med Ydermurene, der bleve opførte af gule Klinker. Foroven tildækkedes Forsøgshuset med ildfaste Sten, der bleve lagte saa tæt op ad hinanden, at der kun blev Spillerum for det fornødne Aftræk for Røgen.

I Bunden af hvert af Forsøgshusets to celleagtige Rum anbragtes 3 kraftige Bunsen-Brændere, altsaa i alt 6 Brændere, som tilsammen brændte ca. 1200 cub. Fod Gas i Timen.

Efter at Forsøgshuset var udtørret, til Slut ved at holde Brænderne svagt brændende, foretoges et Forsøg, hvorved følgende Temperaturer bleve maalte:

Forsøget begyndt Kl. 10⁴⁰ Fm.

— 11 ⁴⁰ —	730 ° C
— 12 ⁴⁰ Eft.	900 —
— 1 ²⁰ —	1000 —
— 1 ⁴⁰ —	1005 —
— 2 ⁰⁰ —	1025 —
— 2 ²⁰ —	1025 —
— 2 ⁴⁰ —	1075 —
— 3 ⁰⁰ —	1085 — Forsøget afbrudt.

Ved et Forsøg, der blev foretaget 2 Dage senere, blev der efter 5 Timers Forløb naaet en Temperatur af ca. 1000 ° C.; en Time senere var Temperaturen stegen til 1100 ° C., hvilken Temperatur nu blev holdt i 1 Time, hvorpaa Forsøget blev afbrudt. Temperaturerne maalt med *Le Chateliers* termoelektriske Pyrometer, som under Forsøget blev anbragt i det ene af de to paa Fotografierne i godt halv Højde synlige, vandrette Jærnrør, medens

det andet kun brugtes for et Par Gange at kontrollere, om Temperaturen var ens paa begge Sider af Tværmuren. Den maalte Temperatur var ikke Maksimumstemperatur, idet Temperaturen syntes at være højere ca. 3 Skifter over Maalestedet.

Da det formentes, at den opnaaede Temperatur af 1100° var

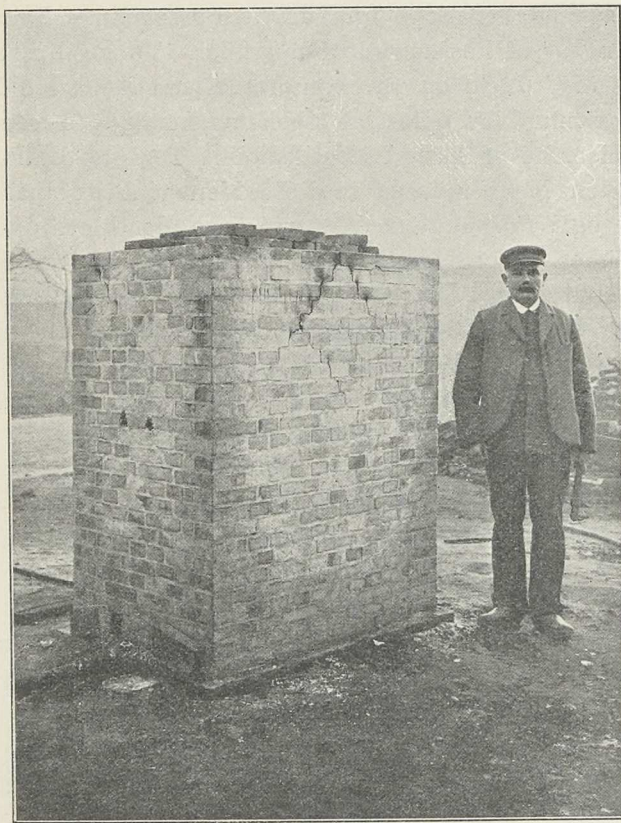


Fig. 13.

tilstrækkelig høj, og at denne Temperatur var bleven holdt en passende Tid, stanse- des Forsøge- ne, og For- søgshusets ene Væg blev nedbrudt, for at man kunde iagttage den paa Stenene skete Virk- ning. For- søgshuset blev nedbrudt saa- ledes, at Tværmurens Vrangside blev synlig, idet det maatte anta- ges, at den paa Stenene

skete Virkning lettest lod sig iagttage her, fordi enkelte af Stenene, da disse ikke vare af nøjagtig samme Længde, her ragede noget ud. Fig. 13 viser Forsøgshuset efter Forsøget, Fig. 14 og 15 samme, efter at en Del af Ydermuren er nedreven, saaledes at Vrang- siden af Tværmuren er synlig.

Af Forsøget fremgik det, at Stenene ikke vare sintrede saa stærkt, at det kunde iagttages, at Murværket paa noget Sted var

sunket kendelig sammen. Angaaende de enkelte Sten iagttoges det, at de sintrede noget paa de Flader, der vare udsatte for Ildpaavirkningen. Eksempelvis skal nævnes, at en Sten, (denne ses paa Fig. 15 i 3die Skifte over Jærnrøret længst til venstre) var sintret saaledes, at Endefladernes Tværsnitsarealer vare henholdsvis ca. 14,5

cm $\times$ 5,0 cm og ca. 14,8 $\times$ 5,4 cm, medens Tværsnitsarealet ca. 4 cm fra Endefladerne og længere inde var ca. 15,5 $\times$ 6,0 cm. Stenen skønnedes at være en af de stærkest medtagne Sten, ligesom det, at den, som det ses paa Fotografiet, paa Vrangsiden ragede langt frem, lader formode, at Stenen har været let brændt i Forhold til de øvrige, idet de lettest brændte Sten ere længst, fordi de ere

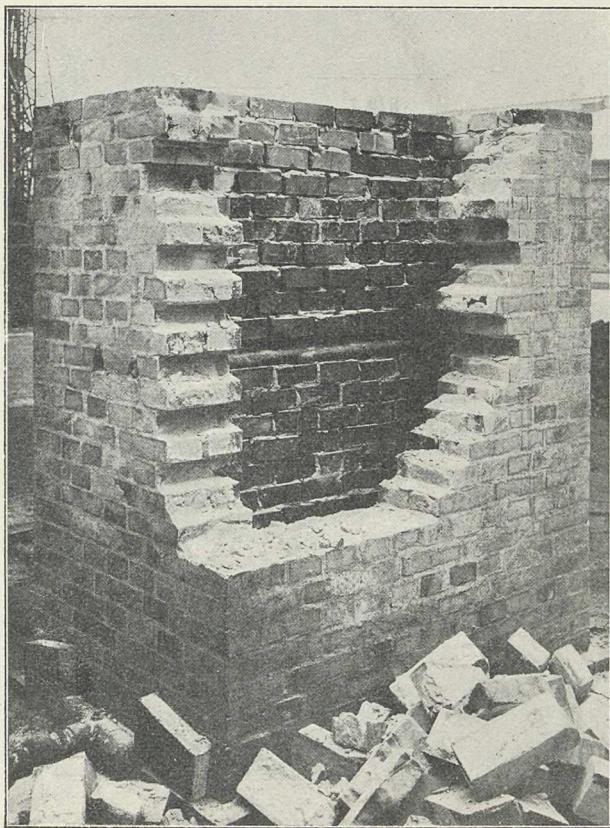


Fig. 14.

svundne mindst ved Brændingen. Fabrikationen af Molersten paa Frederiksholm Teglværk, er i stadig Udvikling. Iblandt nye Anvendelser kan anføres, at der er brugt ca. 40,000 Sten til Frederiksberg Sporvejs- og Elektricitets-selskabs ny, store Kedelanlæg i den ny, elektriske Station paa Finsensvej. Formedelst Stenenes slette Varmeledningsevne ere de anvendte til Indmuring af »Economiserne« og formedelst deres

Lethed til en stor, højt liggende, vandret Ildkanal. Selskabets Ingeniør, Prof. *Bache*, har udtalt sig særdeles anerkendende om Stenene til begge Anvendelser.

Om en anden Anvendelse af Moler, hvorover Anstalten ogsaa har gjort Undersøgelser, kan henvises til Af-snit III g.

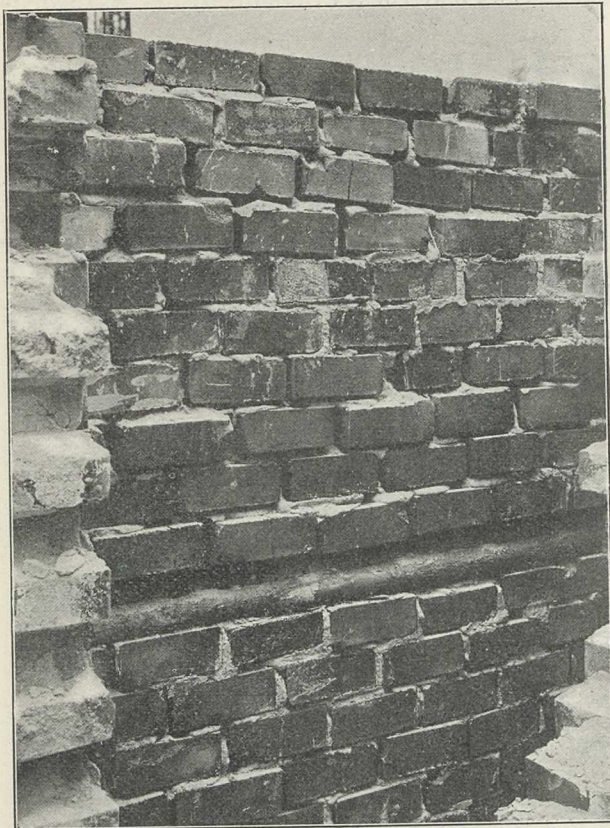


Fig. 15.

c. Prøvning af Kalksandsten.

Hvad de ved Anstalten udførte Undersøgelser over Kalksandsten angaar, turde de være af mest Interesse, som omhandle Frostprøvning af Kalksandsten, hvorom Anstaltens Meddelelse XV handler. Denne har været oversat in extenso paa Tysk i »Tonindustrie-

Zeitung« 1908 Nr. 122 og 125. I det følgende skal der gives et Udtog af denne Meddelelse:

I. Indledning.

I et Tidsrum af ca. 8 Aar havde Statsprøveanstalten anvendt sin almindelige Frostprøve, uden at der nogensinde hverken fra Teglværkernes Side eller fra Leverandører af naturlige Sten var fremkommet Klage over, at denne Prøve var for streng. Da imidlertid for nogle Aar siden Kalksandstenene blev bragte

ind paa det hjemlige Byggemarked, fik Anstalten af og til at høre, at dens Frostprøve maatte være for streng. Dels hed det sig, at trods det, at Stenene frøs i Stykker ved Anstaltens Frostprøve, stode de sig udmærket godt i Praksis, dels blev der meddelt Anstalten, at Sten, der vare prøvede med daarligt Resultat ved Anstalten, havde klaret sig særdeles godt, naar de bleve frostprøvede ved Berliner-Prøveanstalten. Anstalten korresponderede med Berliner-Anstalten om disse Forhold og sendte desuden Sten af en Levering, der var frostprøvet her, ned til Berlin. Det viste sig herved, at disse Sten virkelig klarede sig langt bedre i Berlin end her. For disse Forhold er der iøvrigt alt gjort Rede i Anstaltens Aarsberetning 1906, S. 6. Imidlertid blev der hverken ved den førte Korrespondance eller ved de udførte Forsøg skabt en saadan Klarhed i Spørgsmaalet, at Anstalten derved følte sig foranlediget til at forandre sin Frostprøve. Den 26de Juni 1907 udstedte imidlertid Københavns Bygningskommission en Bekendtgørelse om, at Kalksandsten kun maatte anvendes til Ydermuring, for saa vidt deres Frostbestandighed var konstateret, hvormed mentes konstateret her ved Anstalten.

En herværende Kalksandstensfabrik henvendte sig da til Anstalten og anmodede denne om for sin Regning at foretage indgaaende Forsøg for at faa konstateret, om Anstalten ikke maatte finde Grund til at ændre Frostprøven for Kalksandstens Vedkommende, saaledes at Prøven blev mere i Overensstemmelse med Berlinerprøven.

Forsøgene skulde bl. a. navnlig gaa ud paa at undersøge, om tyske Kalksandsten af de mest anerkendte Mærker vare i Stand til at bestaa Anstaltens Frostprøve.

Endvidere begav Lerlaboratoriets Ingeniør, Hr. *Fischer-Møller* sig efter samme Fabriks Anmodning til Berlin for at se, hvorledes Frostprøven udførtes der. Han blev herved klar over, at Forskellen mellem Berlinerprøven og Anstaltens Prøve væsentlig laa i, at Fordampningen fra Stenenes Overflade var langt stærkere i Berlin end her.

Forudsætningen for en virkelig Frostprøve er den, at Porerne i det Materiale, der skal undersøges, ere fuldstændig eller saa godt som fuldstændig vandfyldte. Naar Vandet da fryser, forøger det sit Rumfang, og det vil da afhænge bl. a. af Stenens Styrke,

men navnlig af Porernes Beskaffenhed, hvor modstandsdygtigt Materialet er over for den med Vandets Udvidelse følgende, sprængende Virkning. Naar en Sten med en Temperatur af ca. $+20^{\circ}\text{C}$ bringes ind i et Rum med en Temperatur af $\div 15^{\circ}\text{C}$, vil der finde en livlig Vandfordampning Sted fra Stenens Overflade, og det tilbageblivende Vand i Stenen maa da tænkes at fordele sig ud over hele Stenens Rumfang. Stenen er altsaa da ikke mere vandmættet, ja det kan endog tænkes, at der kan fordampe saa meget Vand, at, naar Frostene endelig indfinder sig, Vandindholdet i Porerne da er saa ringe, at der overhovedet ingen sprængende Virkning finder Sted. Jo lettere Fordampningen fra Stenens Overflade foregaar, des mindre streng bliver derfor Frostprøven.

I Berlin indspændes Stenene i Bøjler, saaledes at der kan finde fri Fordampning Sted fra hele Overfladen. Her paa Anstalten er Frostprøven imidlertid altid bleven udført saaledes, at Stenene ere blevne lagte ned paa Løbersiderne, dels paa Frysekassens Bund, dels oven paa hinanden. At der paa denne Maade kan indkomme nogen Vilkaarlighed i Prøven, idet det kan tænkes, at nogle af Stenene komme til at ligge noget oftere paa Kassens Bund end andre, skal indrømmes, men Anstalten havde aldrig for almindelige Murstens Vedkommende iagttaget noget, der kunde give Anledning til Betænkelighed i saa Henseende.

Ved den tyske Kalksandstensfabrik-Forenings Generalforsamling i Februar 1908 gjorde Afdelingsforstander ved Berliner-Prøveanstalten, Professor Gary, opmærksom paa¹⁾, at forskellige Prøveanstalter vare komne til andre Resultater m. H. t. Frostprøver med Kalksandsten end Berliner-Prøveanstalten. Han udtalte ved denne Lejlighed netop som sin Mening, at dette rimeligvis væsentlig laa i Forskel m. H. t. Fordampningen under Frysningen. Endvidere nævnte han, at ved Berliner Anstalten foretoges Frysningen i et temmelig stort Rum, hvorved mulig Fordampningen blev noget større end ved de andre Anstalter, hvor Frysningen foretoges i en mindre Kasse. G. knyttede hertil den Bemærkning, at Berlineranstaltens Prøve rimeligvis mere var i Overensstemmelse med Forholdene i Naturen, idet der jo her altid gaves Stenene rigelig Lejlighed til Fordampning. Anstalten skal dog

¹⁾ Tonindustrie-Zeitung 1908, S. 729.

hertil bemærke, at det ikke er saa let en Sag at skønne om, hvilken Prøve der med Hensyn til Fordampningen er mest stemmende med Praxis. Paa den ene Side have jo Stenene i Naturen ikke en Temperatur af 20° , men vel snarere en Temperatur i Nærheden af Frysepunktet, hvorfor Fordampningen naturligvis bliver betydelig mindre end ved nogen af Prøverne; paa den anden Side vil det jo vistnok meget sjældent forekomme, at Stenene i Naturen ere vandmættede eller dog næsten vandmættede, saaledes som ved Prøverne.

At det ikke alene er mellem Berliner-Prøveanstaltens og Statsprøveanstaltens Frostprøver, at der er Uoverensstemmelser, fremgaar bl. a. tydelig af nogle Forhandlinger i et Sektionsmøde i den fransk-belgiske Afdeling af den internationale Forening for Materialundersøgelser d. 26. Januar 1907. Her var bl. a. det Forslag fremme ved næste Kongres at se at faa Konferencebestemmelserne for Frostprøverne nærmere præciserede, da det havde vist sig, at selv om Prøverne paa de forskellige Prøveanstalter udførtes tilsyneladende ens, og efter Konferencebestemmelserne, kom man ofte til ganske forskellige Resultater. Under Forhandlingerne meddelte bl. a. Hr. *Mercier*, at man i Laboratoire des Ponts et Chaussées var gaaet over til at udføre Frostprøven paa den Maade, at man kun lod Stenene indsuge $\frac{2}{5}$ af den højeste Vandmængde, man kunde faa Stenene til at optage paa en bestemt Maade, nemlig ved at anbringe Stenene i en Beholder, hvori man frembragte et delvist Vacuum, derefter indlade Vand i Beholderen, afbryde Vacuumet, naar Stenene vare dækkede af Vandet, og lade Stenene forblive i Vandet i 24 Timer, hvorefter de vejedes. Af de førte Forhandlinger fremgaar imidlertid ikke, at disse Forsøg have været udførte med andre end naturlige Sten.

II. *Undersøgelse af Frostprøvningsmetoder.*

a. *Frostprøvning af Kalksandsten efter forskellige Metoder.*

Til Frostprøvning efter de forskellige Metoder anvendtes 4 forskellige Slags Sten, nemlig Fabrikkens egne Sten og 3 Sorter tyske Kalksandsten, som vare tilvejebragte med Assistance af *Chem. Laboratorium für Tonindustrie* i Berlin, idet Anstalten havde ønsket ved dettes Medvirkning at sikre sig saa vidt muligt at erholde Kalksandsten fra tre af de mest anerkendte og største, tyske Fabrikker.

I de nedenfor meddelte Uddrag af Forsøgsprotokollen omfatte Mærkerne A, B og C de 3 Sorter tyske Kalksandsten, D Fabrikkens egne Sten.

Tabel V. Resultat af Trykprøver med forskellige Sorter Kalksandsten.

Sten-sortens Mærke	Brudbelastning kg pr. cm ² , Middel-tal af 10 Stk. Sten
A	234
B	243
C	113
D	238

Disse Stensorters Styrke mod Tryk fremgaar af hosstaaende Tabel V, idet Trykprøverne udførtes som sædvanlig, ω : Stenene oversavedes paa Midten, og Halvdelenes sammenmuredes med ren Cementmørtel til tærningformede eller omtrent tærningformede Prøvelægemer.

a. Frostprøvning efter Anstaltens sædvanlige Metode.

10 Stk. Sten af hver Sort lagdes først 24 Timer halvt, dernæst 24 Timer helt i Vand. Stenene underkastedes derpaa 25 Frysninger med paafølgende Optøninger. Hver Frysning varede mindst 4 Timer og foregik ved en Temperatur af $\div 10$ til $\div 12^{\circ}$ C., hver Optøning varede ca. 2 Timer og foregik i Vand af ca. 20° C. Resultaterne for de enkelte Stensorter følge nedenfor.

Stensort A.

Samtlige Sten vare beskadigede, 4 stærkere angrebne, 6 viste mindre stærkt eller ganske svagt Angreb.

Nogen Trykprøve med de frostprøvede Sten kunde ikke ske, da Stenene vare for stærkt medtagne.

Stensort B.

3 af Stenene vare lidt beskadigede, de øvrige 7 ubeskadigede.

Ved Trykprøve med de frostprøvede Sten fandtes Middelbrudstyrken at være 241 kg pr. cm².

Stensort C.

8 af Stenene vare meget stærkt angrebne, 2 af Stenene vare ret svagt angrebne.

Nogen Trykprøve med de frostprøvede Sten kunde ikke ske, da Stenene vare for stærkt medtagne.

Stensort D.

Under Prøven blev 3 af Stenene (Nr. 8, 9 og 10) stadig anbragte oven paa de andre Sten, saaledes at de aldrig kom i Berøring med Iskassens Bund eller Vægge.

Stenene Nr. 1—7 samt Nr. 9 vare stærkt angrebne, Stenene Nr. 8 og 10 vare kun svagt angrebne.

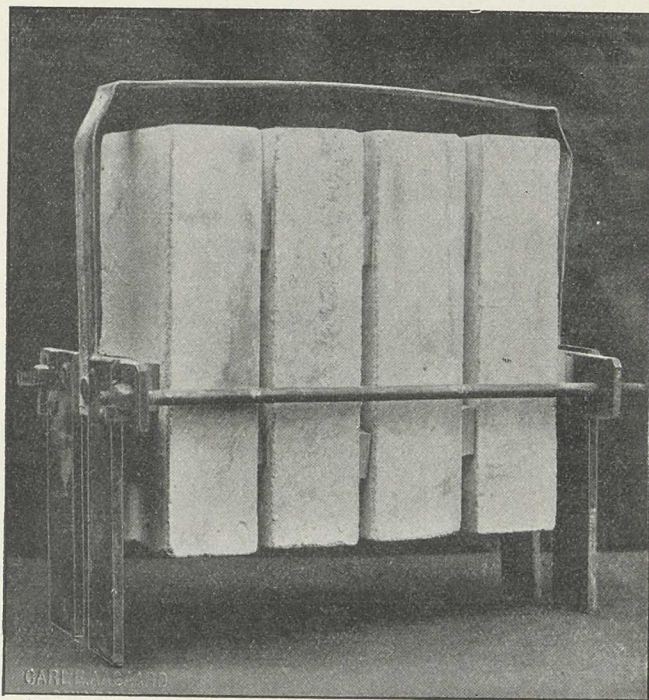


Fig. 16. Indspænding i Bøjle.

Nogen Trykprøve med de frostprøvede Sten kunde ikke ske, da Stenene vare for stærkt medtagne.

β. Frostprøvning af Kalksandsten efter de særlige Metoder.

De Frostprøver, der her er Tale om, udførtes først paa selve Fabrikken, hvorefter Anstalten til Kontrol gentog Forsøgene, og det er kun Anstaltens egne Forsøg, der gøres Rede for her.

De foretoges med 8 Sten af hver Sort. De 4 Sten indspændtes i Jærnbøjler, saaledes som hosstaaende Fig. 16 viser. Der kunde saaledes finde fri Fordampning Sted fra samt-

lige Flader paa Stenene. Til at holde Stenene adskilte fra hverandre anvendtes smaa Træstykker. Da man ved et enkelt af Forsøgene iagttog nogle Afsprængninger, der muligvis kunde skyldes Træets Udbulning, gik man over til at benytte Kautschukstrimler i Stedet for Træstykker. De andre 4 Sten indspændtes ikke, men stilledes ned i Frysekassen med den ene Kopside staaende direkte paa Frysekassens Bund. Der sørgedes for, at disse Sten stadig kom til at staa i Frysekassen med den samme Kopside nedad. I øvrigt foretoges Frostprøven som ellers.

Stensort A.

1) *indspændte i Bøjler.*

Stenene havde øjensynlig ingen Skade lidt.

2) *staaende paa den ene Kopside.*

Paa samtlige Sten var den nedadvendende Kopside helt af-frossen, paa 2 af Stenene fandtes desuden nogle andre, mindre Beskadigelser.

Stensort B.

1) *indspændte i Bøjler.*

Paa 1 af Stenene iagttoges en ubetydelig Afskalning paa et Hjørne af den nedadvendende Kopside. De øvrige Sten havde øjensynlig ingen Skade lidt.

2) *staaende paa den ene Kopside.*

En af Stenene fremviste mindre Afskalning paa to opadven-dende Hjørner. Disse Afskalninger fortsatte sig et Stykke ned ad de tilgrænsende Løbersider. De øvrige Sten havde øjensynlig ingen Skade lidt.

Stensort C.

1) *indspændte i Bøjler.*

3 af Stenene viste meget stærke Angreb paa de nedadvendende Kopsider, idet 1 Sten manglede saa godt som hele Kopsiden, en anden de to Tredjedele, en tredje Halvdelen. Den 4de Sten viste mindre Afskalning paa to Hjørner af den nedadvendende Kopside.

2) *staaende paa den ene Kopside.*

Paa samtlige Sten fandtes de nedadvendende Kopsider affrosne i ca. 1 cm's Tykkelse, desuden fandtes der paa samtlige Sten andre meget betydelige Beskadigelser.

Stensort D.

1) *indspændte i Bøjler.*

Stenene havde øjensynlig ingen Skade lidt.

2) *staaende paa den ene Kopside.*

Paa samtlige Sten vare de nedadvendende Kopsider helt af-

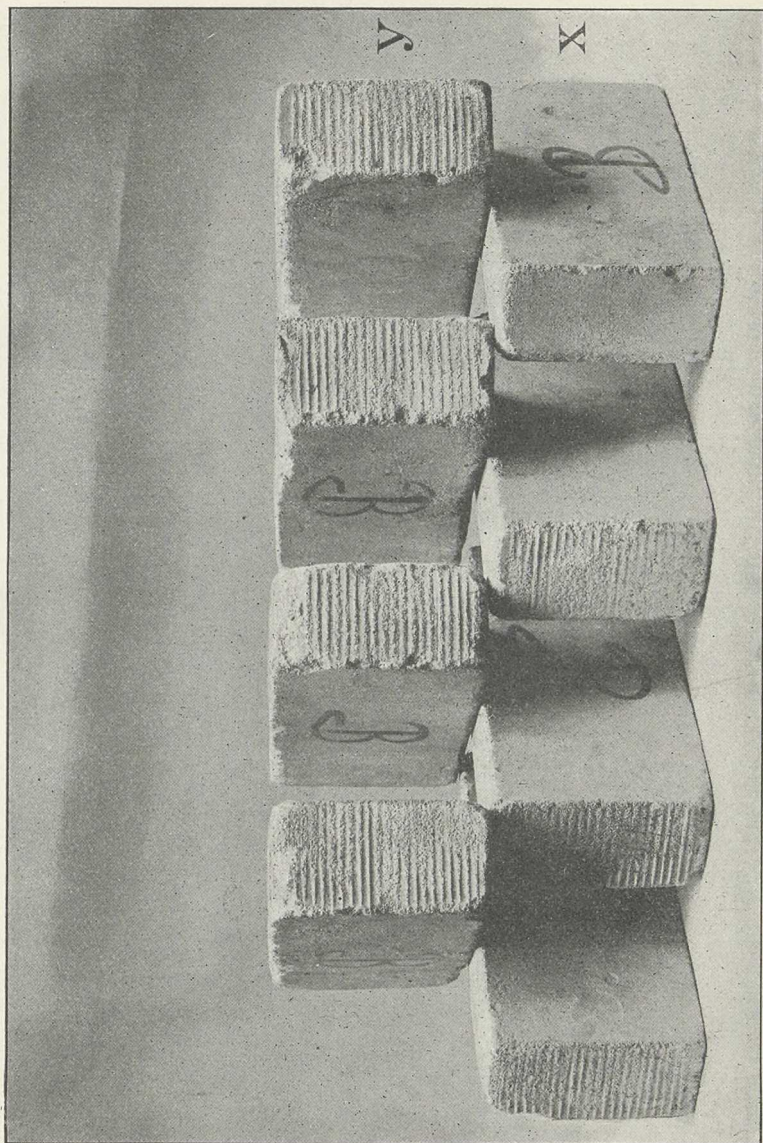


Fig. 17. Kalksandsten frostprøvede efter forskellige Metoder.

frosne, desuden fandtes der en Del andre Beskadigelser i mere eller mindre Grad paa samtlige Sten.

I de hosstaaende Figurer, af hvilke Fig. 17 fremstiller B-Sten, Fig. 18 C-Sten, Fig. 19 D-Sten, udgøres den Række Sten, ud for

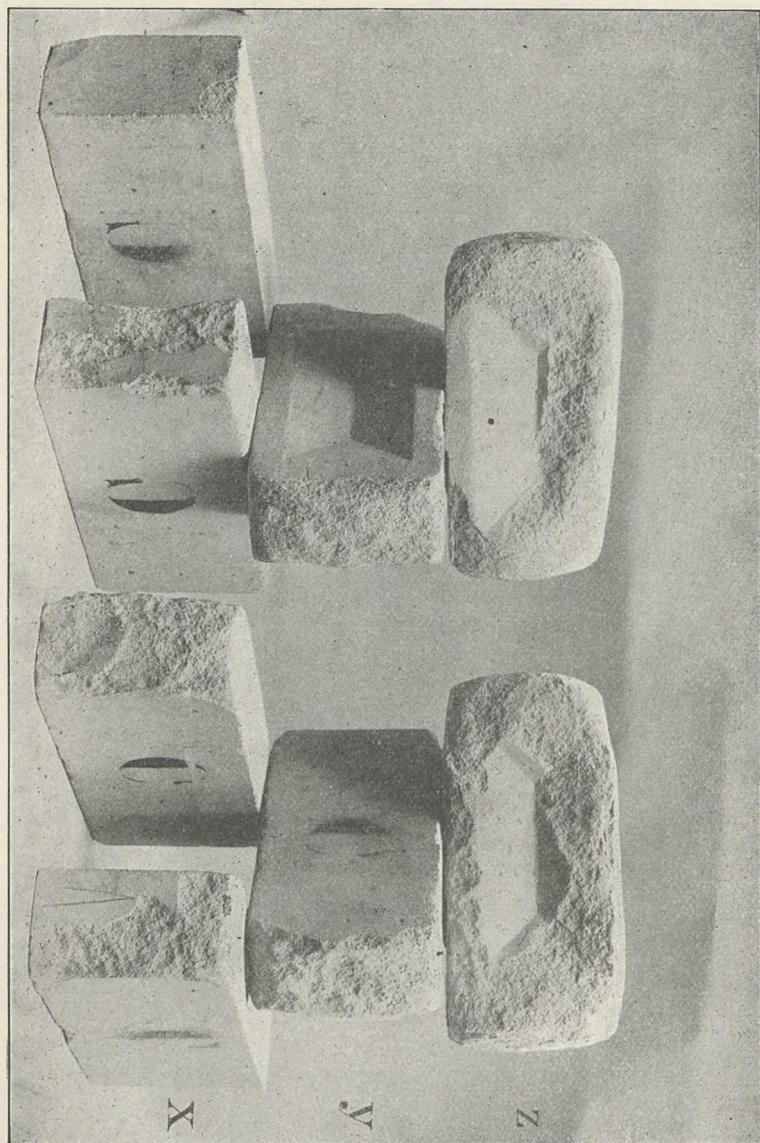


Fig. 18. Kalksandsten, frostprøvede efter forskellige Metoder.

hvilken der staar X, af nogle af de Sten, der have været indspændte i Bøjler, Rækken Y af nogle af de Sten, der have staaet

paa en Kopside, Rækken Z af nogle af de Sten, der have været underkastede Anstaltens almindelige Frostprøve. For B's Ved-

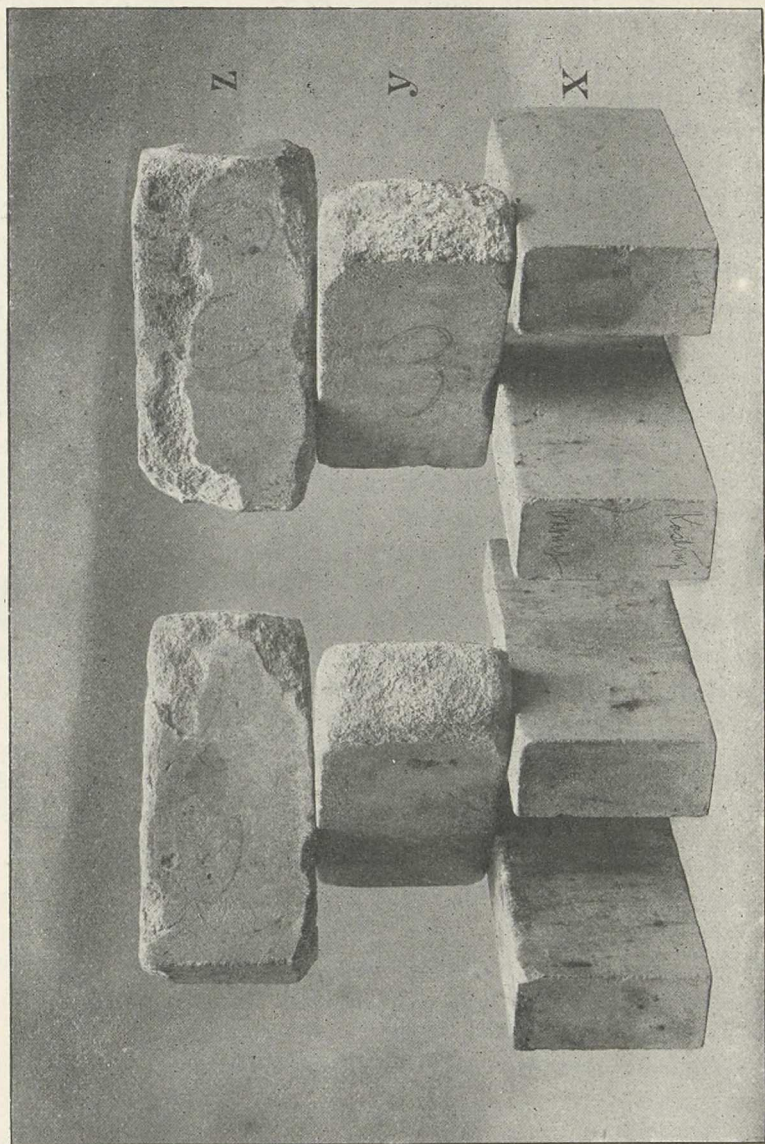


Fig. 19. Kalksandsten, frostprøvede efter forskellige Metoder.

kommende mangler Rækken Z, da disse Sten, som det ogsaa vil fremgaa af det tidligere, bleve trykprøvede efter Frostprøven.

b. *Frostprøvning af brændte Sten efter samtlige Metoder.*

Ved de fornævnte Forsøg var det saaledes konstateret, at Anstaltens almindelige Frostprøve var meget strengere end den Prøve, ved hvilken Stenene indspændtes i Bøjler, og som jo kom Berlineranstaltens betydelig nærmere. Hvor vidt den ændrede Prøve var ganske sammenfaldende med Berlineranstaltens, kunde derimod ikke afgøres; i saa Fald maatte man i begge Tilfælde konstatere de under Frysningen stedfindende Vægttab, hidrørende fra Fordampningen. Derimod var det fastslaaet, at anerkendte¹⁾ tyske Fabrikata ikke kunde taale Statsprøveanstaltens Frostprøve.

Da det paa det Tidspunkt, hvor disse Forsøg foretoges, var Anstalten bekendt, at der paa Christiansborg Slotsplads laa betydelige Bunker af Mursten fra det nedrevne Slot, og det var meget almindeligt, at disse Sten laa og frøs i Stykker, kom Anstalten ganske naturlig ind paa den Tanke at anstille Frostforsøg af samme Art som de med Kalksandsten foretagne, navnlig for at se, om det var tænkeligt, at saadanne Sten, der fryse itu i Praksis, kunde klare sig ved Bøjleprøven.

Stenene vare udtagne af en større Stabel Sten, der hidrørte fra det nedrevne Slot. Talrige af Stenene i denne Stabel vare itufrosne. Stenene vare helbrændte, men for det meste ret uhomogene i deres indre Bygning.

α. *Frostprøvning efter Anstaltens sædvanlige Metode.*

Denne Prøve foretoges med 4 Sten. 2 af Stenene viste sig overordentlig stærkt angrebne, hvorimod de andre 2 øjensynlig vare ganske ubeskadigede.

β. *Frostprøvning efter de særlige Metoder.*

1) *indspændte i Bøjler.*

Efter 25 Frysninger vare samtlige 4 Sten øjensynlig ganske ubeskadigede.

2) *staaende paa den ene Kopside.*

2 af Stenene vare meget stærkt angrebne, de andre 2 en Del angrebne.

¹⁾ Her maa dog indskydes den Bemærkning, at selv om C-Stenene virkelig henregnes til anerkendte Fabrikata, kan de ved Anstalten prøvede Sten neppe gøre Fordring paa dette Prædikat, da de ikke en Gang tilfredsstille den tyske Kalksandstensfabrik-Forenings Minimumsfordringer til Trykstyrke. De viser da ogsaa et fra de andre Sten ganske afvigende Forhold.

Derefter foretoges almindelig Frostprøve med de 6 hidtil ubeskadigede Sten, nemlig samtlige Sten fra den særlige Frostprøve med Indspænding i Bøjle, samt de 2 af Stenene fra den almindelige Frostprøve. De 4 første Sten betegnedes A, B, C og D, de 2 sidste E og F.

A, B og C viste sig meget stærkt angrebne, hvorimod D, E og F øjensynlig vare ganske ubeskadigede.

III. Diskussion af Forsøgsresultaterne.

Da der i Følge ovenstaaende var i hvert Fald en meget stor Sandsynlighed for, at brændte Sten kunde klare Bøjleprøven uden i Virkeligheden at være frostbestandige, blev Anstalten saaledes stillet over for en ny Vanskelighed. Hidtil havde man dog kun tænkt sig den Mulighed at indføre en ny, noget mildere Frostprøve, nemlig Bøjleprøven, og overlade det til Rekvirenterne selv at afgøre, hvor vidt de vilde vælge den strengere eller mildere Prøve. Nu maatte Anstalten jo nærmest stille sig paa det Standpunkt at holde paa, at brændte Sten skulde underkastes den hidtidige Frostprøve, da Bøjleprøven jo ikke lod til at afgive nogen Garanti for Materialets Frostbestandighed. Paa den anden Side kunde man jo ogsaa udtyde Resultatet af de sidst foretagne Forsøg saaledes, at denne Bøjleprøve maaske overhovedet ikke gav nogen Garanti for noget Materiales Frostbestandighed, saaledes at det maaske i det lange Løb vilde vise sig, at Materialer, der i Henhold til denne Prøve vare anerkendte for frostbestandige, alligevel frøs itu i Praksis.

Man stødte saaledes igen paa det Spørgsmaal, der under de foregaaende Forsøg atter og atter havde rejst sig, nemlig, hvori bestaar den store Forskel mellem Kalksandsten og Mursten, der bevirker, at man som Regel kan tage en ganske tarvelig Mursten og lægge den direkte ned paa Iskassens Bund, uden at den tager nogen Skade, medens derimod som Regel de bedste Kalksandsten lide ikke saa lidt derved?

Ganske vist havde man været klar over, at der i de to Materials indre Bygning var nogen Forskel, idet Kalksandsten væsentlig bestod af Sandkorn sammenkittede med Kalkhydrosilikat eller lignende, saaledes, at de ret store Hulrum mellem Kornene have forholdsvis snevre Udgange til hinanden, de brændte Sten derimod af et enten helt porøst Stof, hvorved vi her forstaar et

Materiale gennemfuret af mange Kanaler, eller for de stærkt sandede Stens Vedkommende af Sandkorn sammenkittede af en porøs Masse, uden at det dog var lykkedes herved at forklare Frostens forskellige Virkning over for Kalksandsten og Mursten. — Anstalten mener imidlertid at være kommen til Klarhed over dette Spørgsmaal og skal nedenfor gøre Rede for, hvilke Betragtningssmaader der herved have gjort sig gjældende, samt meddele nogle Forsøg, som synes at bekræfte Rigtigheden af disse Betragtninger.

I en Kalksandsten vil det jo oftest være Tilfældet, at mere end 90 % (efter Vægt) af hele Stenen bestaar af Sandkorn, d. v. s. af et absolut ikke porøst Stof. I Mellemrummene vil der findes et Materiale, hvis Porøsitet ikke ere nærmere bekendt, men dog sandsynligvis næppe stor, og hvis Masse i hvert Fald er overordentlig ringe i Forhold til Sandets, og desuden vil der findes Hulrum, som man maa tænke sig ere betydelig færre i Antal og samtidig betydelig større end Porerne i en almindelig Mursten, da Vandsugningsevne og Vægtfylde for alm. Mursten og Kalksandsten i Almindelighed ikke er meget forskellig. I en brændt Sten af meget sandet Materiale vil vel noget lignende være Tilfældet m. H. t. Hulrummenes Størrelse og Antal som hos Kalksandstenene, men der er dog den væsentlige Forskel, at der i sandede, brændte Sten ikke blot findes Hulrum mellem Kornene, men at disse bestaa af Sandkorn omgivne af et stærkt porøst Materiale. I et saadant Materiale som Kalksandsten er det let forstaaeligt, at det spiller en ret stor Rolle, om Hulrummene virkelig ere vandfyldte eller ej, naar Frosten begynder at tage fat. Hvis de ere fulde af Vand, vil Isen formedelst Hulrummenes snevre Udgange have meget vanskelig ved at udvide sig, uden at der finder en Forskydning Sted af de omgivende Sandkorn, der jo i sig selv ere ganske uigennemtrængelige for Isen.

For den brændte Stens Vedkommende bliver Forholdet et noget andet. Forudsat at Stenen er fuldstændig homogen i sin Bygning, vil Vandet ved Frysningen og den dermed følgende Udvidelse let finde Vej gennem Stenens porøse Materiale; hvis derimod Homogeniteten er mangelfuld, er Forudsætningen for den saaledes foregaaende Fordeling af Vandet (Isen) ud over Stenen brudt, og Forholdet bliver derved ganske ændret. Herfor vil der imidlertid senere blive gjort Rede.

I øvrigt har Anstalten ikke nærmere undersøgt Formen paa Hulrummene i Kalksandsten eller paa Porerne i brændte Sten, saa at det foran udtalte nærmest grunder sig paa Betragtninger, der synes indlysende efter almindeligt Kendskab til de nævnte Materialers Fremstilling.

Den naturlige Slutning af den anførte Betragtningssmaade er den, at Haarrørsvirkningen maa være betydelig større for brændte Sten end for Kalksandsten, hvilket ogsaa

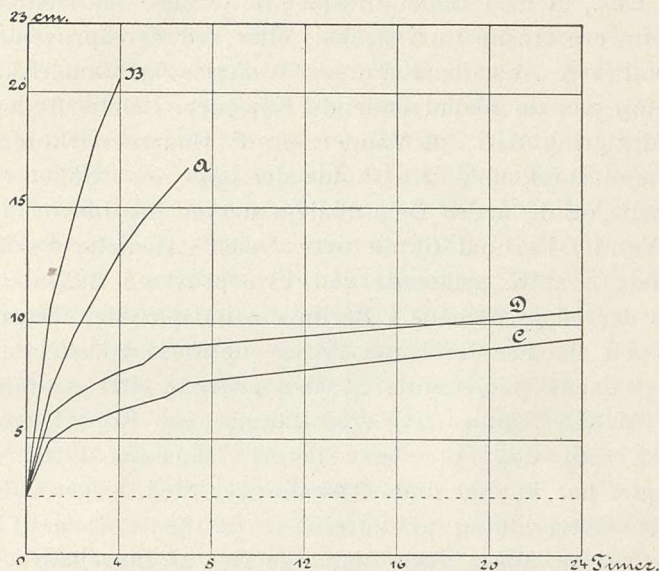


Fig. 20. Grafisk Fremstilling af Haarrørsvirkningen for forskellige Sorter Sten.

har bekræftet sig ved de nedenstaaende Forsøg.¹⁾ Der toges hertil 2 Sorter røde Mursten A og B, og 2 Sorter Kalksandsten C og D²⁾, 3 Stk. af hver Sort. Stenene tørredes til konstant

¹⁾ Anstalten er et Par Maaneder efter disse Forsøgs Afslutning bleven opmærksom paa, at det under en Diskussion i Transact. af Americ. Cer. Soc. IX 07. 693 af Prof. Wheeler er blevet fremhævet, at Regelmæssighed i Porebeskaffenhed er af afgørende Betydning for brændte Stens Frostbestandighed, og at den Hurtighed, hvormed Vand bliver indsuget af Stenene, naar disse delvis neddyppes deri, formenes at afgive et Maal for Frostbestandigheden (Tonindustrie-Zeitung 1908, S. 873).

²⁾ De her brugte Betegnelser C og D have ingen Forbindelse med de i Af-snit II benyttede.

Vægt og vejedes. De anbragtes derefter i en Bakke, hvori der stod Vand til en Højde af 2,5 cm, og det iagttoges nu med 1 Times Mellemrum, hvor højt Vandet steg i Stenene; tillige vejedes Stenene efter 7 og 24 Timers Forløb. Kurverne i Fig. 20 fremstille grafisk Middelhøjden for Vandets Stigning i de 4 Sorter Sten.

De her anførte Forhold forklare forskellige hidtil uopklarede Fænomener. Naar vi holde os til de foran anførte Forsøg, forklares det f. Eks., at de i Bøjler indspændte C-Sten, der efter Opgivelse hverken ere frosne itu i Praksis eller ved Frostprøven i Berlin, derimod ved Anstaltens Forsøg fremvise en Del Afskalninger, og netop paa de nedadvendende Kopsider. Dette finder nemlig sin Forklaring deri, at Vandet, fordi Haarrørsvirkningen ikke har været stærk nok til at holde det oppe, er sunket til Bunds i Stenene, og de nedre Dele af dem derved ere blevne overfyldte med Vand i Forhold til de øvre Dele. At dette Forhold har gjort sig mindre gældende ved Frostprøven i Berlin, kan forklares derved, at Stenene i Berlin ere indspændte i liggende Stilling, ved de her foretagne Prøver derimod i staaende Stilling. Man vil maaske indvende, at Sten prøvede efter Anstaltens hidtidige Metode ogsaa have Afskalninger paa Kopsiden og Liggefladen, som dog ikke have berørt Iskassens Bund. At der desuagtet har kunnet finde Afskalninger Sted, ligger i den ovennævnte Overfyldning af Porerne i de nedre Dele af Stenene. Herved lider altsaa først den ene Del af Liggefladen og Kopsiden Skade. Næste Gang, naar Stenen er kommen til at ligge paa den anden Løberside, overfyldes den anden Del af Kopside og Liggeflade.

Et andet Forhold, der kunde synes at tale imod Haarrørsvirkningens Betydning, er det, der udvises af de Sten, der have staaet paa en Kopside, idet disse ogsaa vise en Del Afskalninger andre Steder end i den nederste Del af Stenen. Det maa dog her tages i Betragtning, at Stenene dels kunne komme i Berøring med Iskassens Sider, dels med hinanden; navnlig vil naturligvis dette finde Sted, naar Stenene have lidt saa meget paa de nedadvendende Kopsider, at Stenene komme til at staa og vakle. Havde de været indspændte, vilde man derfor rimeligvis næppe have iagttaget nogen Afskalning andre Steder end i de nedre Dele af Stenen (Hjørnerne dog undtagne, se nedenfor). Paa de

i Bøjler indspændte Sted iagttoges ogsaa, forsaavidt Stenene overhovedet lede nogen Skade, kun Afskalninger paa den nedadvendende Kopside.

Man maa da antage, at det er en Kombination af en Forhindring af den fri Fordampning fra Overfladen og af en ringe Haarrørsvirkning, som foraarsager Skaden. Herfor taler ogsaa, at Sten, der slet ikke have berørt Iskassens Bund, men blot ligget oven paa de andre Sten, ogsaa kunne have lidt ret betydelig Skade.

Anstalten har senere udført et stort Antal lignende Forsøg m. H. t. Haarrørsvirkningen for brændte Sten og Kalksandsten. For de førstes Vedkommende har man stadig fundet Overensstemmelse med de ovenfor anførte Forsøg. Derimod har man for Kalksandstenenes Vedkommende af og til truffet enkelte Sten med en ret betydelig Haarrørsvirkning. I et enkelt Tilfælde viste 3 Sten af samme Sort stærk Haarrørsvirkning. Disse Sten underkastedes derpaa Anstaltens alm. Frostprøve. Herved viste der sig ingen Afskalninger paa selve Fladerne, derimod vare Hjørnerne paa samtlige Sten mere eller mindre angrebne. De paa-gældende Sten viste iøvrigt en for Kalksandsten ret lav Brudstyrke, nemlig 124 kg pr. cm². Rimeligvis have Hjørnerne da været særlig svage (det viste sig i øvrigt, at af 10 Sten bestode kun de 7 Anstaltens ændrede Frostprøve).

I det hele taget synes Hjørnerne at være et særligt svagt Punkt for Kalksandstenenes Vedkommende. Dette forekommer imidlertid ikke saa besynderligt, naar man betænker, at der her stilles den Fordring, at en Sten med skarpe Hjørner skal udskydes af Formen i en Tilstand, hvor Stenens Masse ikke alene er ganske blød, men ogsaa saa godt som uplastisk. Den store Friktion ved Hjørnerne foraarsager da ganske naturligt en Svækkelse af Sammenhængen mellem Hjørnernes ydre Skal og den øvrige Del af Stenen, noget, der under normale Forhold kun i meget ringe Grad vil gøre sig gældende ved brændte Sten.

Anstalten vil ikke hævde, at Paavisning af en stor Haarrørsvirkning giver en Garanti for en brændt Stens eller en Kalksandstens Frostbestandighed. Navnlig kan det i Henhold til det umiddelbart foregaaende jo meget godt tænkes, at en Sten maaske viser kraftig Haarrørsvirkning og dog mister sine Hjørner ved

Frostprøven. Det er endelig ikke i og for sig givet, at fordi Vandet bevæger sig med Lethed i en Sten, det samme da skulde være Tilfældet med Isen.

Et nærmere Studium af Hulrummenes Form vilde sikkert give værdifulde Oplysninger i saa Henseende.

Tilbage staar at forklare, hvorfor helbrændte Sten under visse Omstændigheder kunne klare »Bøjleprøven«, men ikke Anstaltens almindelige Prøve.

Som allerede tidligere omtalt maa dette Forhold tilskrives manglende Homogenitet hos de paagældende Sten.

Denne Mangel paa Homogenitet kan naturligvis ytre sig paa mangfoldige Maader, og det vilde føre for vidt at gøre Rede for denne Mangels Ytringsmaader i dens forskellige Afskygninger.

Men der skal dog i det følgende søges at give en Forklaring paa, hvorledes Mangel paa Homogenitet kan give sig forskellige Udslag ved de forskellige Frostprøver samt ved Frostens Paa-virkning i Naturen.

Lad os f. Eks. tænke os, at hosstaaende Fig. 21 forestiller en brændt Sten, fremstillet af et i og for sig sandet Materiale, men hvori der paa Grund af mangelfuld Bearbejdelse findes en Stribe A af ikke sandet Materiale. Vi tænker os endvidere, at Stenen er brændt saa haardt, at selve Lersubstansen er sintret, medens det sandede Materiale endnu er ret stærkt sugende.

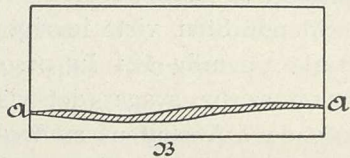


Fig. 21.

Skematisk Fremstilling af Uhomogenitet i en brændt Sten.

Vi vil nu se, hvorledes en saadan Sten vil klare sig overfor Frostvirkninger i følgende 3 Tilfælde:

- 1) Ved Anstaltens almindelige Prøve.
- 2) Ved »Bøjleprøven«.
- 3) Overfor Frost i Naturen.

1) Vi tænker os nu, at Stenen lægges med Løbersiden B ned paa Iskassens Bund. Vandet vil nu, da Fordampning fra Siden B er udelukket, søge at trække sig op igennem Stenen, men støder her paa Striben A, som ikke tillader Gennemgang for Vandet. Følgen bliver da, at den mellem A og B liggende Skal stødes af.

2) Er derimod samme Sten indspændt i Bøjle, saaledes at der kan finde fri Fordampning Sted fra Stenens samtlige Flader, vil den efter al Sandsynlighed ikke lide nogensomhelst Skade.

3) Vi tænker os nu Stenen indmuret saaledes, at Siden B er Facadeside, endvidere, at Murfladen, hvori Stenen er indmuret, vender mod Sydvest. Lad os tænke os, at det i nogle Dage har staaet med sydvestlig Storm og Regn. Den mellem A og B liggende Skæl er da efterhaanden bleven våndmættet, da Striben A forhindrer Vandet i at suge sig længere ind i Stenen. Hvis det nu bliver tørt Vejr igen i nogle Dage med Temperatur over Frysepunktet, vil Størsteparten af Vandet fordampe, og Stenen vil ingen Skade tage. Men slaar Vejret pludselig om til nogle

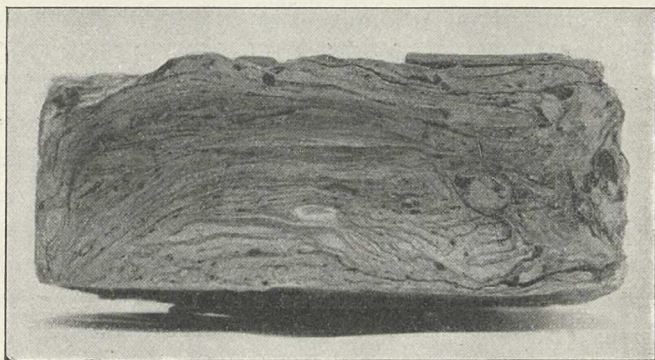


Fig. 22. Snit i en stærkt uhomogen Sten.

Graders Frost, medens Stenen er pjaskvaad, lægger der sig en Isskal uden paa Stenen, som hindrer videre Fordampning af det i Skallen mellem A og B værende Vand. Alt Vandet i denne Skæl fryser, og Følgen vil da meget let blive, at Skallen sprænges af, eller at i hvert Fald dens Sammenhæng med den øvrige Del af Stenen svækkes saa meget, at en Gentagelse af den nævnte Behandling medfører en Afskalning.

Noget lignende vil for øvrigt kunne finde Sted, naar en saadan Sten staar i Stabel ude i Naturen.

Lad os f. Eks. tænke os den samme Sten staaende øverst i en Stenstabel med Løbersiden B opad og med andre Sten paa Siderne. Det har i længere Tid været Regnvejr eller maaske Snevejr med paafølgende Tøvejr. Skallen mellem A og B er

bleven vandmættet. Mellemrummene mellem Stenen og dens Nabosten ere fyldte med Vandhinder eller smeltende Tøsne. Vejret slaar pludselig om til Frost, og Skallen mellem A og B løsner sig.

I Fig. 22 er gengivet et Tværsnit af en i høj Grad uhomogen, tildels itufrossen Sten, hidrørende fra en af Stablerne paa Christiansborg Slots Byggeplads. Man ser tydeligt, hvorledes Frostsprængningerne følger Strukturen i Stenen.

Som ovenfor nævnt kan der selvfølgelig findes mange forskellige Former for Uhomogenitet, der ikke behøver alene at bunde i mangelfuld Bearbejdelse af Leret, men ogsaa kan ligge i andre Forhold. For Eksempel kan der jo ved en mangelfuld Brænding fremkomme »forbrændte« Sten, α : saadanne, i hvilke Overfladen er betydelig haardere brændt end Stenens Kærne. Ogsaa en saadan Art af Uhomogenitet vil kunne give Anledning til Stenenes Ødelæggelse ved Frostvirkninger.

Man vil af det her fremførte, der maaske af nogle vil blive betegnet som en Theori, men som alligevel virksomt støttes af de med Christiansborg-Stenene udførte Forsøg, kunne forstaa, at Anstalten ikke finder sig foranlediget til at ændre Frostprøven for brændte Sten (eller dog kun til at ændre den i den Forstand, at man muligvis vil gaa over til at anbringe Stenene afvekslende med Kopsiderne eller Løbersiderne hvilende paa Iskassens Bund), saa meget mindre som denne Prøve hidtil ikke har givet Grund til nogen Klage hverken fra Teglværkernes eller fra Murmestres og Arkitekters Side.

Enhver uhildet Betragter af disse Forhold vil indrømme, at man ikke for Kalksandstenenes Vedkommende løber nogen større Risiko for at støde paa de her nævnte Arter af Uhomogenitet. Derimod kunde man maaske være tilbøjelig til at antage, at naar Haarrørsvirkningen er mindre for Kalksandsten end for Mursten, maa Fordampningen fra Overfladen ogsaa være væsentlig mindre.

Dette var dog ved en foretagen, sammenlignende Udtørningsprøve for almindelige, flammede Mursten og Kalksandsten ikke Tilfældet i de første 4 Døgn af Udtørringen. Bestemmelsen af Stenenes Udtørningsevne foretoges paa følgende Maade:

De til Bestemmelse af Vandsugningsevnen benyttede, vandmættede Sten henlagdes i Laboratoriet i to Rækker. Stenene vare

anbragte paa Lister. Mellemrummene mellem de enkelte Sten vare overalt de samme. For at gøre Forholdene saa vidt muligt ens for alle Stenene, anbragtes der for Enderne af hver Række en vandmættet Sten af samme Sort som dem, Undersøgelsen omfattede, men som naturligvis ikke medtoges i Vejningerne. Stenene vejedes med passende Tidsmellemrum. Efter at Stenene vare lufttørrede til konstant Vægt, tørredes de til Slut ved en Temperatur af ca. 100° til konstant Vægt.

Tabel VI. Middeltallene af samtlige 10 Forsøgsstens Vægt i g.

	Tørret ved ca. 100° før Vandmæt- ning	I vandmættet Tilstand	Efter Ud- tørring i 26 Døgn	Tørret ved ca. 100° efter Vandmæt- ning og Ud- tørring
Kalksandsten.....	2562	2896	2669	2574
Brændte Sten.....	2263	2602	2264	2261

Som det ses af Tabel VI, sker der for Kalksandstenenes Vedkommende under Vandmætningen og Udtørringen en Vægtforøgelse (gennemsnitlig 0,5 %), for Murstenenes Vedkommende en Vægtformindskelse (gennemsnitlig 0,1 %). Der er dog ikke taget noget Hensyn dertil ved den nedenstaaende, grafiske Fremstilling af Udtørringen, se Fig. 23.

Med Hensyn til Fordampningen fra den vandmættede eller dog stærkt vaade Stens Overflade synes der saaledes ikke at være nogen videre Forskel paa de brændte Sten og Kalksandsten, og det er jo dette Forhold, der har Betydning for det foreliggende Spørgsmaal.

Ved de i Berlinerprøveanstalten foretagne Forsøg af lignende Art er man kommen til det samme Resultat, — sml. *Burchartz*: Die Prüfung und die Eigenschaften der Kalksandsteine, Berlin 1908, S. 89.

Derimod er Anstalten ikke enig med Hr. B. i, at det for en væsentlig Del beror paa en kemisk Omsætning, Kalkhydratets Omdannelse til kulsur Kalk, naar Kalksandstenene ikke efter Udtørringen gaa tilbage til deres oprindelige Vægt. I saa Fald vilde nemlig Størsteparten af denne Vægtforøgelse ikke forsvinde, ved at Stenene opvarmedes til 100° (sml. Tab. VI). Tværtimod

mener Anstalten, at naar Kalksandstenene holde Vandet i betydelig højere Grad tilbage i Hulrummene end de brændte Sten,

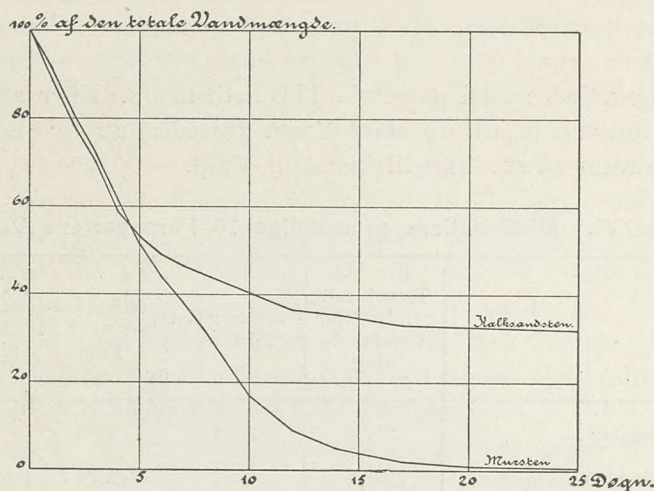


Fig. 23. Grafisk Fremstilling af Udtørringsevn for Sten.

da beror denne Forskel ikke paa Tilfældigheder, men netop paa Forskel i Beskaffenheden af Stenenes Hulrum.

IV. Slutning.

Naar saaledes Fordampningen fra Overfladen af vandmættede eller stærkt vaade Sten ikke er mindre for Kalksandsten end for Mursten, medens Haarrørsvirkningen som Regel synes at være betydelig mindre, er der formentlig ingen Grund til at opretholde en Prøve, hvis Strenghed for Kalksandstenenes Vedkommende væsentlig beror paa et Forhold, som ikke kan ses at have nogen Betydning i Praksis.

Ganske vist er Anstalten tilbøjelig til at mene, at de brændte Sten med Hensyn til Hjørnerne (sml. foran) have en Fordel fremfor Kalksandstenene, men denne Fordel vil træde tilstrækkelig tydeligt frem ved den nye Prøve.

Som Følge af de foretagne Forsøg, og under Hensyn til, at Anstalten stadig savner paalidelige Oplysninger om Kalksandstens Itufrysning i Praksis, har Anstalten ikke ment det forsvarligt længere for Kalksandstens Vedkommende at opretholde en Prøve, som i hvert Fald synes at være for streng, da man dog næppe

vil anvende Kalksandsten paa saadanne Steder, hvor de i vandmættet Tilstand kunne blive udsat for Frost¹⁾. At de under saadanne Forhold skulde yde den samme Modstand mod Frost som gode, helbrændte Sten, tror Anstalten ikke.

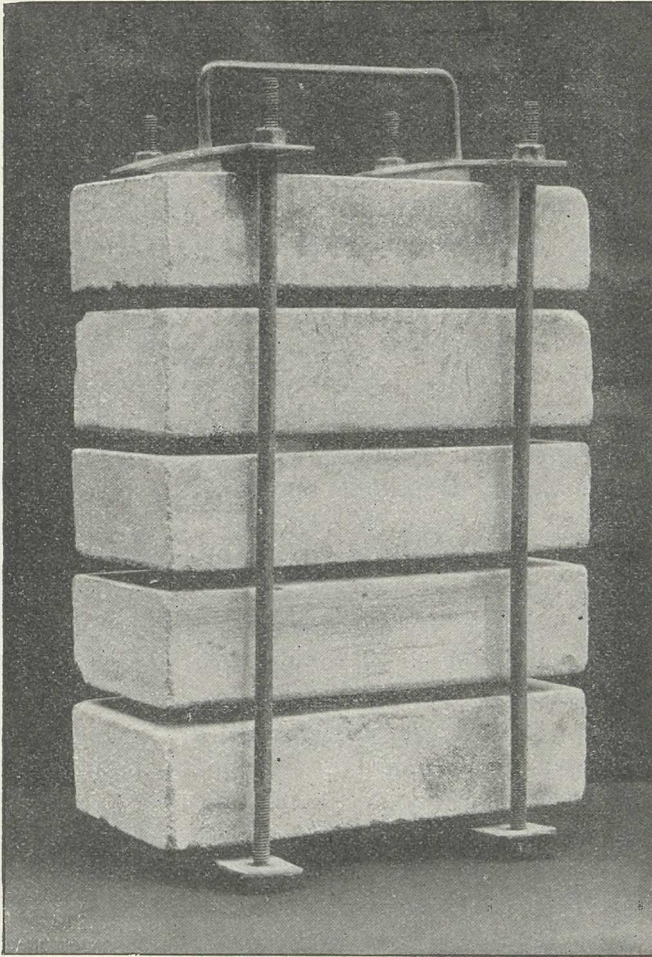


Fig. 24. Ny Indspændingsmaade ved Frostprøvning af Kalksandsten.

Hvad Prøvens Udførelse angaar, da har Anstalten ændret Bøjlernes Form, saaledes som foranstaaende Fig. 24 viser. Stenene

¹⁾ Anstaltens mildere Frostprøve for Kalksandsten har været kritiseret i Tonindustrie-Zeitung 1908, Nr. 149 — en Kritik, som Anstaltens Direktor har imødegaaet i samme Nummer.

indspændes her ligesom i Berlin i liggende Stilling. Ved den viste Konstruktion af Bøjlerne opnaas, at man kan have 2 Bøjler med 5 Sten i hver i en Frysekasse, medens man ved den tidligere Konstruktion kun kunde have 1 Bøjle med 4 Sten i en Frysekasse.

d. Prøvning af Cementmursten.

I de senere Aar er der i Danmark fremstaaet en ikke ringe Industri for Fremstilling af Cementmursten. Denne Industri synes jo ret naturlig for Landet. Anstalten har derfor offentliggjort en Meddelelse XIV om Forsøg med disse Sten. Ved Anstaltens Prøvning af disse Sten har den indtil d. 1. April 1909 prøvet 26 Sorter Sten, dels med dels uden Mørtelfordybninger. Kun i 2 Tilfælde naaede Trykstyrken (Middeltallene) 100 kg pr. cm², og laa i de fleste Tilfælde langt derunder. Middelbrudstyrken af de 17 prøvede Sorter massive Sten, af hvilke der er prøvet mindst 10 Stkr. Sten, bliver 58 kg pr. cm² og for de tilsvarende 9 Sorter Sten med Mørtelfordybninger 55 kg pr. cm².

Hvad Frostprøverne angaar, viste det sig, at Cementmurstenene paa ingen Maade kom paa Højde med brændte Sten, idet man sikkert kan regne med, at enhver helbrændt Mursten taaler Frostprøven, medens ingen af de prøvede Cementmursten udholdt den. Det maa dog bemærkes, at Anstalten senere har ændret sin Frostprøve for Kalksandsten — se under c —, og at det paatænkes mulig ogsaa at indføre den ændrede Frostprøve for Cementmursten.

I det sidste Aarstid er der ved Anstalten rekvireret paabegyndt en længere Række Forsøg med Fremstilling af Cementmursten i forskellige Blandingsforhold og under Anvendelse af forskellige Sorter Cement og Sand. Fremstillingen af Stenene foretoges paa forskellige Tider af Aaret (for ogsaa at undersøge Aarstidens Indflydelse paa Stenenes Styrke) paa en Cementmurstensfabrik i Jylland under Anstaltens Kontrol, medens Trykprøvningen af de fremstillede Prøveserier foretoges paa Anstalten med visse Tidsmellemlum. Forsøgene fortsættes fremdeles.

e. Prøvning af Ler- og Cementrør for udvendigt Tryk.

De Prøver, som Anstalten har udført i denne Retning og hvorom den tidligere har offentliggjort Meddelelse XIII¹⁾, ere paa

¹⁾ Et Udtog af denne Meddelelse findes i Tonindustrie-Zeitung 1907, S. 1695.

ganske faa Undtagelser nær udført paa den af den internationale Kongres i Bryssel i 1906 efter Prof. Garys Forslag anbefalede Metode, idet nemlig Trykket ved disse Forsøg har virket langs enkelte Frembringere, og kun disse Forsøg ere medtagne i de efterfølgende Tabeller.

Til disse Prøver anvender Anstalten for Rør til og med en indvendig Diameter af 6" (16 cm) *Tinius Olsen*-Maskinen, — se Meddelelse I —, hvori endnu Rør af denne Dimension kunne faa Plads.

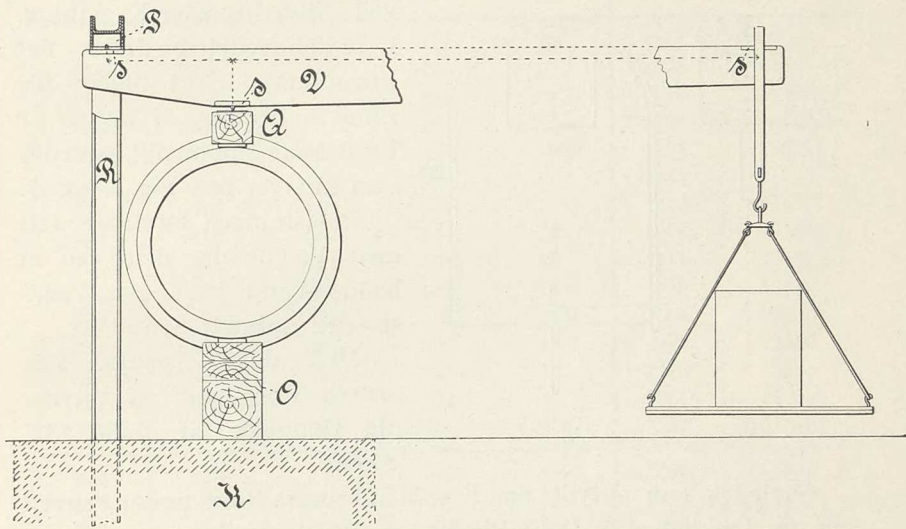


Fig. 25.

Anstaltens Apparat til Prøvning af Rør af Diameter over 6" er et Vægtstangsapparat, der er vist paa Fig. 25—27. R — se Fig. 25 — er en Ramme af $\square$ -Jærn, der er indstøbt i en meget stor Betonklods K. Rammen bestaar af 2 Stkr. lodrette $\square$ -Jærn, der foroven ere forbundne ved et kort Stykke vandret $\square$ -Jærn, hvortil er fastboltet en Knivpande P. Mod denne Knivpande ligger selve Vægtstangen V an med sin ene Knivseg.

Vægtstangen er en Træbjælke, hvori der er indfældet 3 Staalplader s; i den første er der anbragt den nævnte Knivseg, som ligger an mod Rammens Knivpande, i den

anden Knivseggen, som overfører Trykket til Røret, og i den tredje en Bolt, som foroven er forsynet med et Kørnpunkt, der tjener til Anbringelse for Vægtskaalen med Belastningen. Man har nemlig anset det for hensigtsmæssigt ikke at ophænge Vægtskaalen paa en Knivseg, men at benytte en Ophængning, der i noget større Maalestok er vist paa Fig. 26 og 27. I Staalpladen s findes et aflangt Hul, hvori Boltens b kan forskydes i Vægtstangens Længderetning og derpaa fastspændes, saaledes at man kan sørge for, at Vægtstangsforholdet stadig er 1:10, selv om Træbjælkens Længde skulde forandre sig noget

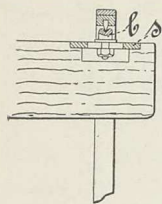


Fig. 26.

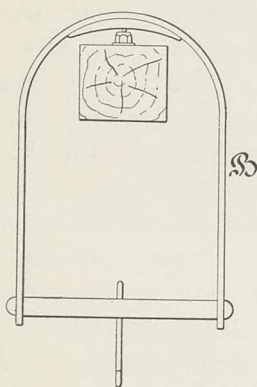


Fig. 27.

ved Udtørring eller Kveldning. I Boltehovedet b findes det Kørnpunkt, hvori Bøjlen B's Pinol anbringes. I Bøjlen er Vægtskaalen ophængt, saaledes som angivet paa Fig. 25 og 27.

Belastningen foretages dels med Vægtlodder dels ved at hælde Vand i en paa Vægtskaalen anbragt Spand.

Med dette Apparat kan prøves Rør med en udvendig Diameter af indtil 32" (84 cm).

Saaledes som antydnet paa Fig. 25 anbringes Røret under Prøven paa en Opklodsning O af Bjælke- og Plankestykker, der ere anbragte paa Betonfundamentet K. Trykket overføres til Røret gennem et Bjælkestykke Q, hvorpaa der foroven er fastskruet et Stykke Jærnplade som Anlæg for Knivseggen.

Mellem Opklodsningen og Røret saavel som mellem Bjælkestykket Q og Røret anbringes et Stykke ca. 15 mm tyk Filt for at fordele Trykket saa jævnt som muligt over hele Rørets Længde. Under Prøven anbringes Røret saaledes, at hele Længden med Undtagelse af Muffen paavirkes til Tryk.

Da der, saavidt Anstalten bekendt, kun fra faa Steder er offentliggjort Talværdier for Knusningsforsøg med Ler- og Cementrør, skal Anstalten her meddele samtlige Resultater indtil den 1. Juli 1909.

Tabel VII. (Lerrør.)

Udvendig Længde	Udvendig Længde til Muffen	Indvendig Længde til Muffen	Indvendig Diameter	Gods- tykkelse	Brudbelastning	
					Total	kg pr. m ² vandret Tværsnits- areal
mm	mm	mm	mm	mm	kg	
660	562	588	112	15	956	11980
680	582	608	120	16	819	9230
680	588	621	116	16	1006	11600
687	582	606	113	15	703	8390
667	567	588	117	16	1116	13170
641	543	575	154	20	1814	17210
628	539	582	154	20	1358	13000
719	628		150	18.4	1653	14100
857	765		150	18.4	2207	15340
680	582	615	150	19	1713	15250
673	575	615	150	19	2255	21190
673	575	602	147	19	2212	21590
703	618	657	157	19	1668	13760
703	618	654	157	19	2111	17420
654	575	602	157	18.6	1909	17150
680	588	628	144	18.9	2394	22300
654	575	602	150	15.9	982	9400
687	598	628	157	17	1275	11250
677	585	618	154	17	1267	11380
677	588	621	154	17	1237	11310
863	758		248	21.7	1340	6040
667	579	615	229	19	1263	7080
667	575	615	229	19	918	5150
680	575	611	298	25	1618	6870
677	582	611	301	26	1703	7090
673	579	624	324	25	1352	6210
687	585	631	320	25	1272	5790

Tabel VIII. (Cementrør).

673	608	638	105	20	1713	19760
673	605	638	105	20	1805	21050
680	615	647	154	23	867	7040
693	592	660	170	22	1170	9130
673	562	634	157	22	1195	11130
673	562	634	157	21	1058	9940
673	562	634	157	21	1300	12210
673	562	634	157	21	1141	10710

Udvendig Længde	Udvendig Længde til Muffen	Indvendig Længde til Muffen	Indvendig Diameter	Gods- tykkelse	Brudbelastning	
					Total	kg pr. m ² vandret Tværsnits- areal
mm	mm	mm	mm	mm	kg	
677	602	628	157	24	1410	11360}
677	602	634	157	24	1585	12770}
680	598	628	154	26	1405	11320}
680	602	628	154	26	1122	8970}
680	602	628	154	26	1220	9750}
693	588	654	170	22	1862	14760
700	595	660	170	22	1463	11420
700	595	660	170	22.5	1492	11650
647	549	608	154	21.5	664	6180
651	549	615	154	21.5	951	8860
677	598	628	157	21	699	5860}
680	598	634	157	21	1070	8980}
680	605	641	157	24	1721	14090
641	536	602	150	22	1258	11930
647	549	611	150	22	1187	11050
	602		157	24	807	6550
	602		157	24	685	5560
680	602	634	157	23	1031	8440
680	602	631	157	23	1063	8700
657	608	631	157	23	1007	8180
700	592	660	167	22	1031	8110
665	590	620	155	25	1453	12010}
665	590	620	155	25	1283	10600}
670	575	615	150	28	1270	10510}
660	575	620	150	28	1511	13140}
820	740	780	230	27	1503	7130}
820	735	780	230	32	1473	6910}
835	750	800	230	28	3123	14610}
835	750	800	230	28	2283	10680}
798	700	772	229	25	2385	12420
811	706	772	229	26	800	4060
811	706	772	229	26	970	4920
840	752	788	235	25	1403	6530
840	749	798	235	25	1612	7510
840	752	804	235	27	732	3360}
837	752	794	235	27	961	4410}
811	700	768	229	25	1359	7070
837	752	791	209	26	1286	6560
837	752	791	209	27	1424	7190
843	745	798	262	32	1381	5700
843	745	798	262	33	1270	5200

Udvendig Længde mm	Udvendig Længde til Muffen mm	Indvendig Længde til Muffen mm	Indvendig Diameter mm	Gods- tykkelse mm	Brudbelastning	
					Total kg	kg pr. m ² vandret Tværsnits- areal
847	739	785	317	31	626	2230}
843	739	798	317	31	870	3100}
817	703	772	304	28.5	1072	4220
850	745	791	307	32	1481	5350}
850	745	794	307	32	1563	5640}
840	739	804	314	32	1882	6650}
840	742	804	314	33	2332	8220}
873	732	785	314	35	1434	5090
863	732	794	314	35	1285	4560
824	752	791	317	34	1225	4230
845	750	800	310	35	963	3380}
845	750	800	310	35	1063	3730}
863	732	817	396	35	1252	3660
843	752	791	376	34	819	2480
817	693	768	379	33	841	2730
837	729	788	389	35	1024	3060
820	700	770	375	35	1603	5150}
820	700	770	375	35	1673	5370}
830	715	765	380	45	1893	5630}
835	735	780	375	47	1783	5160}
855	740	800	470	46	1493	3600}
860	745	805	470	46	1123	2690}
820	700	770	450	39	1433	3860}
820	700	770	450	39	2043	5510}
1007	879	942	471	40	1396	2880
853	732	798	471	39	1406	3000
850	732	798	484	39	1544	3280
853	739	794	471	38	753	1860}
853	739	794	471	38	764	1890}
900			549	78	1633	2570}
890			549	78	2353	3750}
961	876	955	553	50	2829	4950
961	883	948	553	54—51	2038	3520
994	883	951	543	50	1016	1800
857	749	811	536	46	1638	3490}
857	749	811	536	46	1680	3570}
1004	896	945	628	55	1608	2430}
1007	902	948	624	55	1870	2820}

I foranstaaende Tabel VII er anført Resultatet af Trykprøverne med alle de Lerrør, som Anstalten har prøvet indtil 1. Juli 1909. I Tabel VIII findes Resultatet af Trykprøverne med Cementrør indtil samme Dato. Tegnet } betyder, at to eller flere Rør af samme Dimensioner ere indsendte og prøvede samtidig.

Som det vil ses, er der i Tabellerne foruden Rørenes Dimensioner og Total-Brudbelastningen tillige opgivet Brudbelastningen i kg pr. m² vandret Tværsnitsareal, hvor det vandrette Tværsnitsareal er beregnet som Produktet af den udvendige Diameter og Rørets udvendige Længde til Muffen.

Rørene, der omhandles i Tabellerne VII og VIII, have alle været almindelige, runde Mufferør. Kun i nogle faa Tilfælde har Blandingsforholdet og Alderen af de prøvede Rør været opgivet.

Det maa jo imidlertid antages, at Rørene ikke ere blevne indsendte til Prøve, førend de ere blevne ansete for brugsfærdige, d. v. s. have henstaaet tilstrækkelig længe til Hærdning.

Som det ses, er Antallet af prøvede Rør med andre Dimensioner end 6" = ca. 160 mm kun ringe, saa at Resultaterne ikke kunne siges at give noget fyldestgørende Billede af, hvad man kan forlange i Retning af Styrke mod udvendigt Tryk for andre end 6" Rørene.

Af disse er der derimod prøvet ikke saa faa, nemlig 15 Stk. Lerrør og 31 Stk. Cementrør. Det er da egentlig kun for 6" Rørene, at Anstalten har naaet det Maal, den har villet tilstræbe ved Offentliggørelsen af Resultaterne, nemlig dels at en Leverandør, som lader sine Rør prøve, skal kunne finde Tal til Sammenligning med de for hans egne Rør fundne, dels at Tallene skulle være til Nytte ved Udarbejdelsen af Leveringsbetingelser, ved at give et Begreb om, hvad man kan forlange. Som Middeltal bliver Brudbelastningen for 6" Lerrør 15 400 kg pr. m² og for 6" Cementrør 10 030 kg pr. m² vandret Tværsnitsareal.

f. Forsøg paa at fremstille vejrbestandig Cementpuds uden Revner.

Disse Undersøgelser bleve udførte for en af Kbhvns. Magistrat nedsat Kommission for at finde en Maade, hvorpaa man kunde restaurere Dekorationen paa *Thorvaldsens Museum* i København. Denne Dekoration bestaar dels af store, ensfarvede Felter, hovedsagelig gule, dog ogsaa sorte, grønne eller hvide, dels af en Række billedlige Fremstillinger udenpaa Musæet i mange Farver og forestillende Thorvaldsens Hjemkomst til Kbhvn.

og til Gaarden i faa Farver forestillende Løvværk, Palmer, kørende Genier, dekorerede Vaser m. m. De billedlige Fremstillinger ere udførte som indlagt Arbejde af farvet Cement. De ensartede Felter bestaa ogsaa hovedsagelig af farvet Cement, idet dog de gule Felter have et Lag Kalkmaling ovenpaa den farvede Cement. Hist og her findes i øvrigt blaa og røde Linier, Friser eller Lister om Felterne.

Den nævnte gule Maling er skallet af eller sidder løs. Naar man fugter den med Vand, kan man fjerne hele det gule Pudslag med en Spatel, hvad der ikke lader sig gøre f. Eks. med det sorte Pudslag efter Fugtning. Under den gule Maling ser man mange Steder, at den gulfarvede Cement næsten har mistet sin Farve. De billedlige Fremstillinger have for en stor Del ligeledes mistet Farverne, rundt omkring ses den farvede Puds at være forvitret, og overalt er Cementpudsen baade i Felterne og de billedlige Fremstillinger fuld af Revner. Det er rimeligt at antage, at disse have bidraget væsentlig til Pudsfladernes Ødelæggelse i Tidens Løb; Vand og Snavs trængte ind i Revnerne, og ved Vandets Frysning udvidedes de, ligesom Snavset gav Anledning til Svampekulturer, der paa mange Maader bidroge til Pudsens og Farvernes Ødelæggelse.

Revnerne hidrøre som bekendt fra Cementpudsens Kontraktion ved Afbindingen. Ved Materialprøvningskongressen i Paris i 1900 forelagde Prof. *Henry Le Chatelier* Resultaterne af en Række af ham nogle Aar tidligere begyndte Forsøg over Formindskelsen af Cementmørtels absolute Volumen ved Afbindingen, som han kort i Forvejen havde offentliggjort i Bull. de la Soc. d'Encouragement 1900, pag. 54. Ved samme Kongres forelagde Statsprøveanstaltens Direktør nogle ved Anstalten udførte Forsøg dels til Paavisning af denne Kontraktion, dels til Paavisning af, at Kontraktionen kunde modvirkes ved at behandle de pudsede Flader med Kesslers Magnesiafluat¹⁾. Anstaltens Meddelelse VI²⁾ omhandler imidlertid ikke blot disse Forhold, men ogsaa forskellige andre, saaledes Undersøgelser over forskellige Cementsorters Alkalitet og Undersøgelser over, hvorledes denne Alkalitet bedst modvirkes. Iblandt de Midler,

¹⁾ Kongresberetningens sidste Bind S. 183, Udtog af en Beretning af G. A. Hagemann og H. I. Hannover.

²⁾ Oversat paa Tysk i »Baumaterialienkunde« 1903, Hefte 12 og 1904, Hefte 7, 8 og 11—12.

der prøvedes i dette Øjemed, viste Fluat sig at være bedst egnet for farvede Cementflader og virkede tillige til at gøre Pudsen tæt. Endvidere omhandler nævnte Meddelelse de Undersøgelser, som Anstalten gjorde for at finde passende Farvestoffer til Indblanding i Cementmørtel, idet som bekendt mange Farvestoffer ødelægges ved en saadan Indblanding.

Undersøgelserne blev gjort ved Statsprøveanstalten af et af de i Note 1 Side 75 nævnte Herrer bestaaende Underudvalg, som var valgt af Kommissionen, og dette Underudvalg lod gøre forskellige Restaureringsforsøg paa løse Flager, deriblandt i Foraaret 1900 en større Prøve af den billedlige Fremstilling, der indeholdt 8 forskellige Slags farvet Puds. Denne Prøve taalte Sommeren igennem at staa i Solhede og Regn uden at revne, og ganske vist fik 3 af de 8 Slags farvet Puds en stor Del meget fine Revner i den paafølgende Vinter, men de 5 andre stode ude i 3 Sommerses Solskin og Regn, og to Vinteres Frost, og i indtil ca. 50° C Varme og indtil ÷ 12 à 13° C Kulde uden at revne, og uden at de nævnte fine Revner syntes at tiltage i Antal eller Størrelse.

Senere er der af Københavns Magistrat udført en Restaureringsprøve efter noget nær denne Metode paa selve Musæet ved den sædvanlige Indgang. Men heri opstod der snart slemme Revner. Aarsagen hertil kan være at søge forskellige Steder, f. Eks. i at Farveindblandingen har været en anden, i at der er glittet med en anden Haardhed, eller i at der ved Prøven paa den løse Flage har fundet nogen Kontraktion af Dekorationen Sted, uden at det er blevet bemærket ved at medføre Revnedannelse, fordi nemlig maaske selve Flagen ogsaa har trukket sig sammen. Det meget vanskelige Problem er derfor endnu ikke løst, men i alt Fald i én Retning synes der at være et paalideligt Resultat, nemlig ved at der er udfundet en Række holdbare Farvestoffer.

g. Forsøg med delvis at erstatte Kalk i Kalkmørtel med Moler.

Ved den første Forsøgsrække gik man ud fra en Mørtel med et Indhold af 8 % tørt Kalkhydrat. Som Sand benyttedes en ligelig Blanding (efter Vægt) af Normalsand og Klitsand. I den nævnte Mørtel erstattedes dernæst Halvdelen af Kalkhydratet med Moler.

Der formedes Trykprøvelegemer, som sædvanlig paa *Böhmes* Hammerapparat. Efter 28 Dages Ophold i et stærkt fugtigt Rum — Fugtighedsgraden i dette Rum er senere bestemt til ca. 90 % — underkastedes Prøvelegemerne Trykprøve.

Resultatet ses af nedenstaaende Tabel IX.

Tabel IX. Trykprøver med Kalk-Molers-Mørtel.

Mørtel- blanding	Mørtel A	Mørtel B
	8 % Kalkhydrat 92 % Sand	4 % Kalkhydrat 4 % Moler 92 % Sand
Middeltal for 10 Prøvelegemer	3,0 kg pr. cm ²	31,8 kg pr. cm ²

Det viste sig saaledes, at Styrken steg overordentlig stærkt ved at erstatte Halvdelen af Kalkhydratet med Moler. Som det imidlertid vil ses af den næste Forsøgsrække, have Forholdene ved den første Forsøgsrække været ret ugunstige for Kalkmørtelen og særlig gunstige for Kalk-Molersmørtelen, ved at Lagringen skete i et stærkt fugtigt Rum.

Ved den anden Forsøgsrække gik man ud fra en Mørtel med et Indhold af 5 % tørt Kalkhydrat.

Som Sand benyttedes en Sort Mursand, samt Kalk, der indkøbtes i Handelen.

I den nævnte Mørtel erstattedes dernæst de 3 % Kalkhydrat med Moler.

Der fremstilledes 10 Prøvelegemer af hver Mørtel. Af disse 10 Prøvelegemer anbragtes de 5 i et stærkt fugtigt Rum, de andre 5 anbragtes paa en Hylde i Cementlokalet. Resultatet af Trykprøverne efter 28 Dages Forløb ses af nedenstaaende Tabel X.

Tabel X. Trykprøver med Kalk-Molers-Mørtel.

Mørtel- blanding	Mørtel C		Mørtel D	
	5 % Kalkhydrat 95 % Sand		2 % Kalkhydrat 3 % Moler 95 % Sand	
	opbevaret i stærkt fugtigt Rum	opbevaret i Cementlokalet	opbevaret i stærkt fugtigt Rum	opbevaret i Cementlokalet
Middeltal for 5 Prøvelegemer	1,9 kg pr. cm ²	6,0 kg pr. cm ²	5,1 kg pr. cm ²	4,3 kg pr. cm ²

Det vil heraf ses, at medens Moleresmørtelen i hvert Fald tiltager lidt i Styrke ved at henstaa i et stærkt fugtigt Rum fremfor i forholdsvis tør Luft, er ganske det modsatte Tilfældet med den ublandede Kalkmørtel, som efter 28 Dages Forløb har opnaaet 3 Gange saa stor en Brudstyrke ved Opbevaring i forholdsvis tør Luft som ved Opbevaring i stærkt fugtigt Luft. Af Tallene ses videre, at man af Kalkhydrat i en Mørtel med $5\frac{1}{2}\%$ Kalkhydrat omtrent maa kunne erstatte det halve med Moler, uden

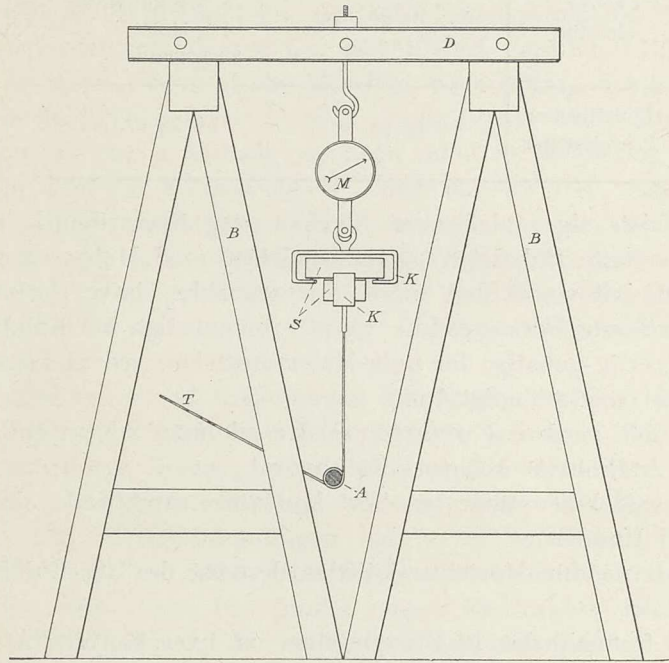


Fig. 28.

at Styrken bliver synderlig mindre i et Rum af Cementlokalets Fugtighed — hvor Fugtigheden er ca. 65 % —, medens der i et stærkt fugtigt Rum vindes meget i Styrke ved Molerets Anvendelse i nævnte Mængde.

De nævnte 2 Mørteler benyttedes endvidere til Adhæsionsforsøg.

Adhæsionsforsøg havde Anstalten tidligere udført paa den bekendte Maade ved at mure to Sten sammen overkors og trække dem fra hinanden efter en vis Tids Forløb. Til at trække dem fra hinanden brugtes det i Fig. 28 viste, primitive Apparat, for-

synet med nogle antydede Smaaskruer efter den af *v. d. Kloes* i »Baumaterialienkunde« 1900, S. 154 givne Anvisning.

Ser Stenene, hvorom der griber Kløer *K*, af hvilke den øverste er ophængt i et Dynamometer, der atter er fastgjort til Dobbelt-drageren *D*. Der trækkes i den nederste Klo, naar en Mand ved Haandkraft drejer Maskinakslens *A*, og samtidig en anden trækker i den frie Ende af det om Akslen *A* nogle Gange viklede Tov *T*. Akslen drejes ved at tage i et derpaa siddende, lille Svinghjul.

Det anførte Apparat har vist sig hensigtsmæssigt i flere Tilfælde, idet Akslen *A* hører til en forhaandenværende Maskine, og Bukkene *B* kunne hensættes som vist paa Figuren paa begge Sider af Akslen og det justerede Dynamometer *M*, der viser det udøvede Træk til Adhæsionens Overvindelse.

I det foreliggende Tilfælde udførtes dog Adhæsionsforsøgene paa følgende, kendte Maade:

Der benyttedes almindelige, flammede Mursten, der sammenmuredes 3 og 3 med Liggefladerne mod hinanden, saaledes at i hvert Sæt den midterste Mursten ragede med sin ene Kopende ud over de to andre. Stenene henlaa i Anstaltens Kælder i ca. 8 Uger. Adhæsionsforsøgene udførtes paa Jærnprøvemaskinen ved at trykke mod den midterste Stens fremspringende Kopende, som om man vilde drive Stenen tilbage til at flugte med de to Ydersten.

Forsøgsresultaterne for de enkelte Prøvelegemer stemte ret daarligt overens, som Tilfældet plejer at være ved Adhæsionsforsøg.

For Mørtel *C* fandtes Brudbelastningen at variere fra 0,2—1,6 kg pr. cm², Middeltallet 0,6 kg pr. cm².

For Mørtel *D* fandtes Brudbelastningen at variere fra 0,3—0,8 kg pr. cm², Middeltallet 0,4 kg pr. cm².

Man kan heraf slutte, at hvis Halvdelen af Kalkhydratet i en Mørtel med 5 % Kalkhydrat erstattes af Moler, vil Adhæsionen i hvert Fald ikke blive synderlig formindsket.

Anstalten maatte formene, at det efter det saaledes foreliggende vilde vise sig fordelagtigt at erstatte en stor Del af Kalkhydratet i Kalkmørtel med Moler og navnlig paa fugtige Steder.

Moleret er da ogsaa kommet i Anvendelse ved Frederiksholms Kalkværk til Fremstilling af Kalkmørtel, og det har vist sig, at

Laboratorieforsøgene bleve bekræftede, og at Kalk-Molers-mørtelen er særdeles behagelig at arbejde med.

h. Undersøgelser over Maling paa frisk, overfladetør eller fugtig Cementpuds.

Disse Undersøgelser ere paa Foranledning af afdøde Stadsarkitekt i Kbhvn., Prof. *Fenger*, udførte for Kbhvns. Magistrat, og gik ud paa at finde, hvorledes man kunde male, navnlig oliemale paa Cementpuds, idet Oliemaling som bekendt ikke holder paa frisk Cementpuds, saaledes ikke, hvor Cementpuds nylig er repareret, f. Eks. paa Væggene i Badeanstalter.

Da Statsprøveanstalten ansaa det kemiske Angreb, der hidrører fra selve Pudsen, for i det overvejende Antal Tilfælde at være det vigtigste, udførte den Forsøgene paa en saadan Maade, at man var sikker paa, at denne Paavirkning blev den, der kom til at virke alene, og den udførte dem som Laboratorieforsøg.

Som en af de Sidepaavirkninger, der kunne fremkomme ved praktiske Forsøg, skal nævnes det Tryk, Vandet i fugtigt Murværk kan være underkastet. At efterligne denne Paavirkning paa en fuldstændig naturlig Maade vil ved Laboratorieforsøg frembyde store Vanskeligheder, saa store, at Statsprøveanstalten ikke mente, at den kunde overvinde dem, naar Forsøgene ikke skulde blive for kostbare.

I den om Forsøgene handlende Meddelelse X, gøres der først Rede for, hvorfor frisk Cementpuds angriber Oliemaling, saa at man almindeligvis bør lade gaa 1 à 2 Aar, før man oliemaler paa Pudsen, og dernæst gøres der Rede for de Metoder, man har til at modarbejde den nævnte skadelige Indvirkning. Endelig omhandles der, hvilke Stoffer, der have været brugte ved Forsøgene, og hvorledes disse udførtes dels paa frisk, overfladetør Cementpuds, dels paa frisk, fugtig Cementpuds.

Som Resultat af Forsøgene skal her anføres, at blandt den halve Snes prøvede Stoffer var det saakaldte Fluociment, opfundet af *Kessler*, det bedste til Maling paa frisk Cementpuds, naar den var overfladetør, hvortil dog kun krævedes, at den var et Par Uger gammel, medens det saakaldte Kautschukbutter fra Chemische Fabrik *Busse*, Hannover—Linden, var det bedste paa frisk, fugtig Cementpuds og i øvrigt ogsaa særdeles godt paa frisk, overfladetør Cementpuds. I Afhandlingen nævnes sluttelig

en Del andre Stoffer, der gaa i Handelen til samme Brug, men som ikke bleve medindtagne i Forsøgsrækken.

Ved de under f omhandlede Forsøg kom Anstalten ind paa at male paa Puds med Cement- og Kalkfarver, f. Eks. at male med en Blanding af Cement og Farve, og gøre Malingen afvaskelig ved at behandle den med Fluat. Ved den Lejlighed prøvede daværende Assistent ved Anstalten, Frk. Ingeniør *Klingberg*, at erstatte Fluat med en fortyndet Opløsning af Oksalsyre eller en koncentreret Opløsning af oksalsur Ammoniak, idet f. Eks. ultramarinfarvet Puds ikke kan taale Oksalsyre, men vel oksalsur Ammoniak, og hun anvendte disse Stoffer ikke blot ved Cementmaling men ogsaa ved Kalkmaling for at gøre den afvaskelig. Nærmere derom indeholder Slutningen af Anstaltens Meddelelse VI.

i. Undersøgelser over Linolie og Rustbeskyttelsesmidler.

Disse Undersøgelser ere udførte for Ministeriet for Kirke- og Undervisningsvæsenet og offentliggjorte i Meddelelse XII. Den første Del, som handler om Undersøgelser over Linolie, var Genstand for et Foredrag af Prof. *N. G. Steenberg*, under hvis Ledelse de vare udførte, paa den internationale Kongres for anvendt Kemi i Berlin i 1903 og findes i Oversættelse paa Tysk i Beretningen derfra. Den anden Del har følgende 4 Hovedafsnit: Jærnets Rustdannelse, Beskyttelse af Jærnet mod Rust ved Overtræk af forkellig Art, om Angreb af Jærnet trods Maling, og hvorledes dette kan tænkes, samt: Prøvning af Rustbeskyttelsesmidlers Værdi. Det sidste Afsnit falder i to Dele, hvoraf den første giver et Uddrag af forskellige Meddelelser om tidligere Forsøg, dels praktiske Prøver, dels Laboratorieforsøg, medens den sidste Del omhandler Statsprøveanstaltens egne Forsøgsrækker.

Disse bestaa for en stor Del Rustbeskyttelsesmidlers Vedkommende i:

- 1) Bestemmelse af Farveforbruget,
- 2) — - Tørringsevnen,
- 3) Udsættelse for Ophedning til 150° — 160° C,
- 4) — - Svovlbrinteluft,
- 5) — - Svovlsyringluft,
- 6) — - Chlorbrinteluft,

- 7) Udsættelse for Vanddamp ved Atmosfæretryk,
- 8) — - spændte Vanddampe,
- 9) Samtidig Udsættelse for Luft, Kulsyre og Vanddamp,
- 10) Udsættelse for kogende Vand,
- 11) — - Akkumulatorsyre (Svovlsyre af Vf. 1,15),
- 12) — - en 3 % Kogesaltopløsning med Tilledning af
Luft og Kulsyre,
- 13) Prøvning af Modstandsevnen mod Slid,
- 14) Undersøgelser af selve Farvehinderne navnlig med Hensyn
til Gennemtrængeligheden for Vædske,
og foruden disse Forsøgsrækker, der udførtes som Labora-
torieforsøg, endnu i følgende praktiske Forsøgsrækker:
- 15) Udsættelse for Røggas og
- 16) Ophængning ved et Tjærebassin paa Kbhvns. østre Gasværk.

Der angives nu nærmere i omtalte Meddelelse XII, hvorledes Farverne bleve malede paa smaa Stykker Jærnplader enten med Glødskal paa eller efter dennes Fjernelse ved Neddypning i Glycerin-Svovlsyrebejdse, paafølgende omhyggelig Skylning med Vand samt Polering med fint Smergellærred.

Hvad nu f. Eks. Tørringsevnen angaar, bestemtes denne ved at bestemme det Tidspunkt, da den paastrøgne Farve havde opnaaet konstant Vægt, idet det antoges, at man herved fik et ret godt Maal for Farvernes relative Tørringsevne, medens denne Fremgangsmaade selvfølgelig praktisk set intet kunde ud-
sige om deres absolute Tørringsevne. Den konstante Vægt blev opnaaet efter fra 1 til 18 Døgn, idet Antiferugin var 18 Døgn om at naa den.

Hvad Udsættelsen for Ophedning til 150 à 160° angaar, foretoges den i Tørreskab i 2 × 6 Timer, og efter Ophedningen foretoges forskellige Bøjningsprøver, dels med fuldstændig skarp Sammenbøjning, dels om Dorne af forskellig Diameter, og til Sammenligning foretoges de samme Bøjningsprøver med malede Blikplader, der ikke havde været ophedede, og det angaves, om Farvelaget revnede eller ej ved de forskellige Bøjninger eller blev smuldrende.

Hvad f. Eks. Udsættelsen for Chlorbrinteluft angaar, viste det sig, at for Blikplader med Blyhvidt og en hvid Emaillefarve var Malingen allerede helt ødelagt efter 4 Timers Forløb, medens de andre Farver taalte flere Timers Paavirkning, lige op indtil 20 Timer, som taaltes af Antiferugin.

Det vilde føre for vidt at gøre Rede for Resultaterne af de mange, forskellige Forsøg her. Kun skal det særlig nævnes, at Forsøgsrækken 13 over Modstand mod Slid udførtes ved at lade Sand af bestemt Kornstørrelse falde fra en bestemt Højde paa malede, cirkulære Jærnplader, 10 cm i Diameter. Forsøgene udførtes med det i Fig. 29 viste Apparat. A er en Tragt, der er ophængt i den over Trisserne a og a_1 gaaende Snor b ; Tragten bærer to paa hinanden vinkelrette, vandrette Arme c og c_1 (sidstnævnte kun synlig som et Punkt paa Figuren), der ere forsynede med Øjer, hvorigennem Snorene b og b_1 gaa. Arme og Snore skulle hindre Tragten i at svinge. Tragten's Udløbsaabning kan lukkes ved Proppen d , der ved den deri fastgjorte Snor let og hurtigt kan rykkes ud.

Lodret under A stilles Apparatet B, der skal opfange det fra A fallende Sand. I B findes en ved 3 Stivere e støttet, vandret, cirkulær Skive f med samme Diameter som de anvendte, malede Plader. C er en Beholder til Opsamling af Sandet. Forsøget udførtes saaledes: Tragten's Udløbsaabning lukkedes med Proppen d og Tragten fyldtes med ca. $1\frac{1}{2}$ kg Sand og hejsedes op i en saadan Højde, at Afstanden fra Udløbsaabningen til Pladen f var ca. $2\frac{1}{2}$ Meter. Derpaa bleve de malede Jærnplader anbragte paa Skiven f , d fjærnedes ved et rask Ryk i Snoren, og Sandet begyndte at falde og samle sig sluttelig i C efter at

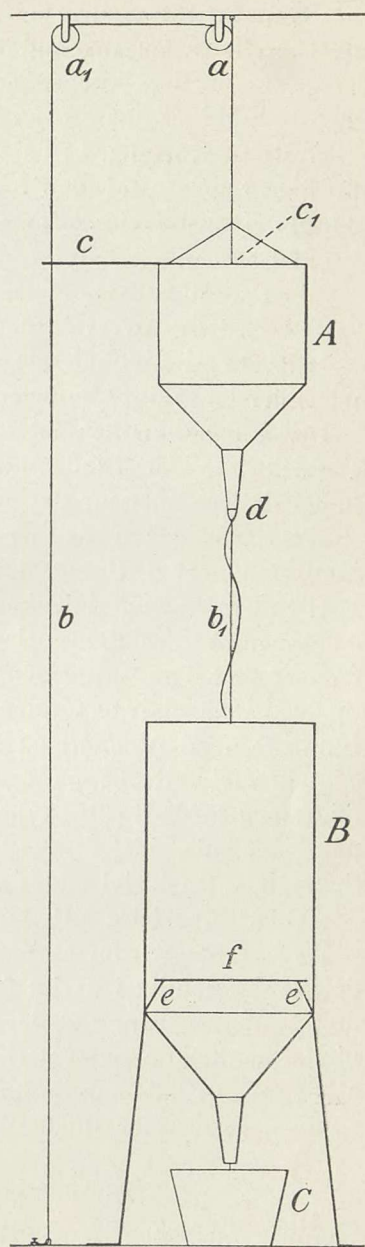


Fig. 29. Apparat til Slidforsøg.

have paavirket de malede Plader. — Denne Proces kunde efter Omstændighederne gentages flere Gange ved samme Plade.

Der anvendtes til Forsøget 2 forskellige Sorter Sand, dels Berliner-Normalsand (Sand I), dels Klitsand af en saadan Kornstørrelse, at det passerede en Sigte med 400 Masker pr. cm^2 , men holdtes tilbage af en med 900 Masker pr. cm^2 (Sand II). Viste det sig nemlig, at en Farve øjeblikkelig blev slidt igennem ved Anvendelsen af den først nævnte Sandsort, forsøgte den mindre Kornstørrelse. Paa Grundlag heraf indordnedes Farverne i 4 Klasser.

Her skal kun anføres, at til 1ste Klasse, den modstandsdygtigste, kom overvejende saadanne Rustbeskyttelsesmidler til at høre, hvori Linoliefernis var brugt som Bindemiddel, hvilket uden Tvivl skyldes Linoliefernisens Elasticitet, altsaa det samme Forhold der bevirker, at Linoleum staar saa godt mod Sandstraaleblæst. Er Bindemidlet skørt, springer Rustbeskyttelsesmidlet lettere af, naar det rammes af Sandstraalen.

Beretningen om de her omtalte Slidforsøg, hvoraf der her kun er givet et Udtog, har i øvrigt været oversat in extenso paa tysk i Baumaterialenkunde 1905, S. 168. Der er dér tillige gjort Rede for, at Benyttelse af en Sandstraale til Slidforsøg — navnlig paa Træ — formentlig første Gang er sket her i Landet (se den i 1893 udgivne, foran omtalte Undersøgelse af Forstkandidat, Ingeniør C. V. Meldahl) og tillige er der dér begrundet, hvorfor Sandstraaleblæst næppe egner sig til Slidforsøg med Træ. Til Slidforsøg med Rustbeskyttelsesmidler synes Sandstraalen mere paa sin Plads, idet f. Eks. Malingen paa Standere til elektriske Sporveje uden Tvivl slides meget af flygende Støv og Sand.

Da af Meddelelse XII kun det lille Afsnit om Slidforsøgene hidtil har været oversat paa et fremmed Sprog, er denne Meddelelse formentlig i øvrigt forblevet ubekendt, de nordiske Lande dog undtagne, hvor det danske Sprog forstaas. Af en Aarsberetning fra Stockholms Materialprøvningsanstalt ses det da ogsaa, at denne Anstalt har indført flere af de af Statsprøveanstalten angivne Prøver for Rustbeskyttelsesmidler.

k. Forsøg vedrørende Trækonserveringsmidler.

Disse Forsøg, som ere udførte efter Forslag af Driftsbestyrer *Irminger* ved østre Gasværk i Kbhvn. ere ligeledes udførte for



Fig. 30.

Ministeriet for Kirke- og Undervisningsvæsenet, og foreløbige Beretninger om dem ere afgivne af Statsprøveanstalten i Meddelelse XI og af Driftsbestyrer *Irminger* som Formand for et Udvalg, der har planlagt dem, i Statsprøveanstaltens Aarsberetninger for 1907 og 1908.

Til Forsøgene er der benyttet Træstykker af Rødgran, Hvidgran, Fyr og Bjergfyr samt Eg, — Hvidgran og Bjergfyr dog kun enten som Hegnsstolper eller i Form af Rundlægter som Stativer, hvorpaa der henlagdes nogle Granstykker og Fyrrestykker vandret over Jorden. I øvrigt blev der af Rødgran, Fyr og Eg paa ganske bestemt Maade tildannet et meget stort Antal Forsøgsstykker til Anbringelse i Jorden, enten vandret nede i denne, eller vandret med den øverste Flade (en Marvside) i selve Jordoverfladen, eller lodret halvt nedgravede i Jorden, og en Del af dette Materiale forblev i upræpareret Stand, medens en anden og større Del blev præpareret paa 82 forskellige Maader ved Maling, Imprægnering, o. s. v.

Hele Forsøgsmateriellet befinder sig 6 km fra Kbhvn. ved Husum Station, paa et af 2den Ingeniørdirektion velvillig overladt Terræn og ses paa Fig. 30, og Hensigten er efterhaanden at undersøge Vejrligets Indflydelse derpaa. Endnu foreligger kun nogle faa Resultater, — se Anstaltens Aarsberetninger for 1907 og 1908, — men til Efteraaret er det Hensigten at begynde en nøjere Undersøgelse af Materiellets Tilstand.

Anstaltens Meddelelse XI gør nærmere Rede for, hvorledes Træet blev udskaaet af Stammerne, hvorledes der er passet paa, hvilken Side af Træet, der vendte mod Nord, hvorledes der blev gjort Optegnelser over Harpikshuller, Tykkelsevækst, Knastrigdom m. m.

Fig. 31 viser Træet stablet til Tørring efter Udskæringen.

Forinden Træet blev præpareret, blev der anstillet en Del Undersøgelser dermed. Saaledes blev der foretaget Vægtfylde- og Fugtlighedsbestemmelser og Foranstaltning truffet til at kunne bestemme Askeindholdet, ligesom der blev henlagt en Del Træ til Bestemmelse af Styrken mod Bøjning, som efter et Par Aars Forløb blev udført paa Statsprøveanstalten.

For nemlig at faa et Talresultat for, hvor stærkt det lodret anbragte Træ raadner i Jordlinien, er det Hensigten at brække det og undersøge, hvor meget det har tabt i Styrke. Ved Bøj-

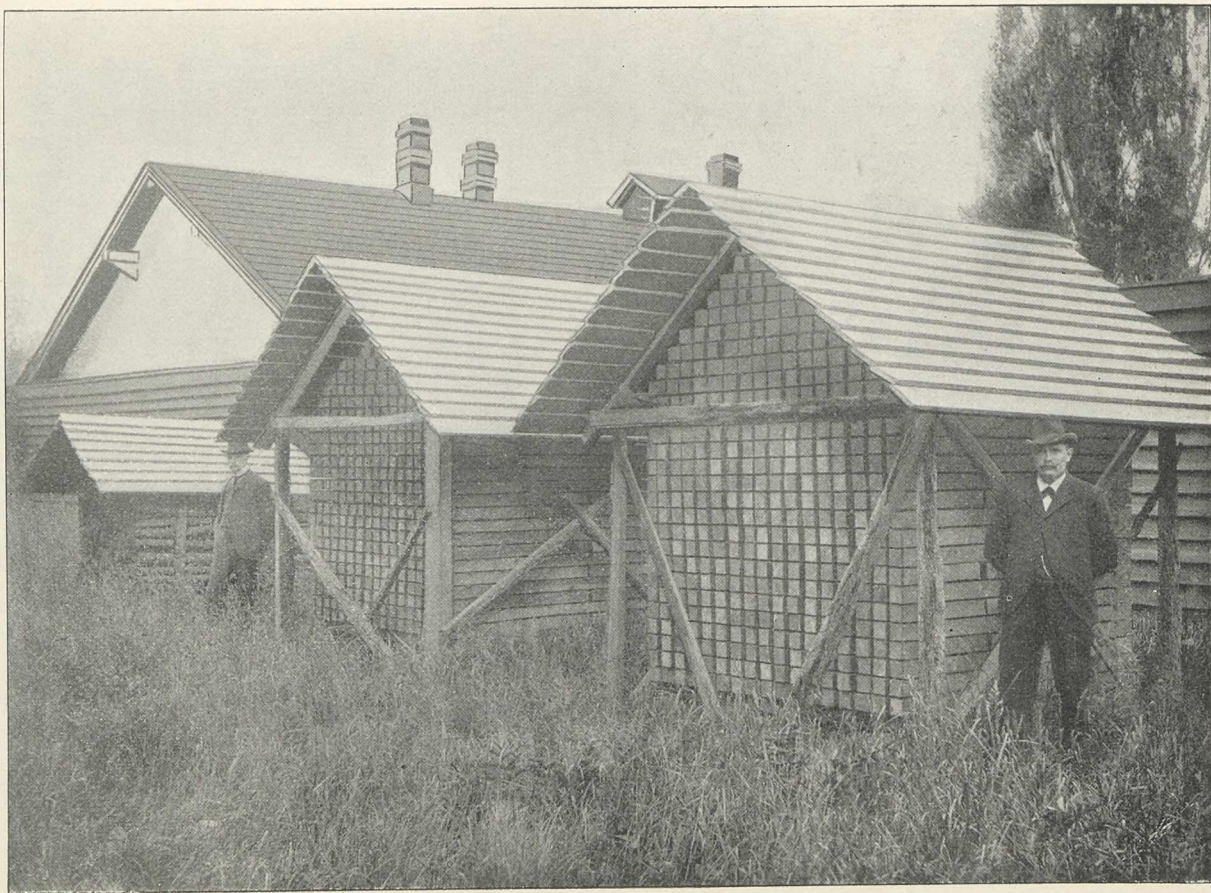


Fig. 31.

ningen bliver det ikke brækket ved Paavirkning lige paa Midten, hvor det jo netop vil have lidt mest, men i en Afstand af $\frac{1}{3}$ af den frie Længde fra den ene Understøtning.

Det er hovedsagelig Kemiker ved Østre Gasværk, Ingeniør *C. J. H. Madsen*, som for Udvalget har udført det betydelige Arbejde, der har været med at holde Orden paa Materialet, lede Præpareringen paa alle de mange Maader o. s. v.

Saa vidt vides er denne Forsøgsrække den største, der er i Gang i sin Slags. Efter at Planen dertil var udarbejdet og Bevillingen givet, fandtes det, at der flere Aar forinden var begyndt Forsøg i lignende Retning i Finland, men mindre omfattende, og en Række Forsøg af lignende Art har Prof. *M. E. Henry* ved *École nationale des Eaux et Fôrets* i Nancy berettet om paa neden-nævnte Sted ¹⁾.

Allerede i 1895 har i øvrigt Dansk Skovforening paabegyndt sammenlignende Forsøg mellem svensk og dansk Grans Holdbarhed ved at opføre 8 ens Skure, hvori de to Træsarter ere anvendte vekselvis. Ved Eftersynet i 1907 syntes det, at dansk Gran havde en noget større Modstandsevne, men Forsøgene fortsættes ²⁾.

1. Forsøg angaaende Imprægnering af Træ mod Brand.

Anstalten har i Aarenes Løb gjort en Del Forsøg til Bedømmelse af, hvorledes forskellige Overstrygningsmidler beskytte Træ mod Brand. De have været gjorte i et lille, dertil lavet Apparat, hvori Træet indlagdes i Form af en Rundstok i forskellige Højder over en Række Gasblus, hvorefter man iagttog dels hvor mange Sekunder det varede, før de første Gasarter, der fremkom ved den tørre Destillation, antændtes, og dels naar Træet virkelig brød i Brand, hvilket sidste Moment dog ikke er let at fastslaa. Der skal her ikke gaas nærmere ind paa disse Prøver, hvorom hidtil intet er publiceret, men derimod gøres Rede for en Brandprøve med imprægneret og uimprægneret Træ, der er udført for *Akts. Dansk Imprægneringskompagni* i Kbhvn., og hvorom nærmere er anført i Anstaltens Aarsberetning for 1908.

¹⁾ »Le Génie Civil« af 19. September 1908.

²⁾ Tidsskrift for Skovvæsen, Bd. XX, 1908.

Forsøgenegik ud paa at finde, hvor lang Tid det tog at gennembrænde nogle sammenpløjede Træflager af et Par Kvadratmeters Størrelse.

Den ved Forsøgene benyttede Anordning var følgende: I et Forsøgshus opført til samme Brug, og hvoraf Fig. 32 viser dels et lodret Snit a-b, dels Forsøgshuset set fra oven, anbragtes de omtalte Træflager i en skraa Stilling, som vist i det lodrette Snit, saaledes at Flammen fra 3 derunder liggende Gasbrændere kunde slikke op ad Flagerne. Under Forsøget kunde Temperaturen maales ved Hjælp af *Le Chateliers* elektriske Pyrometer, idet dette anbragtes

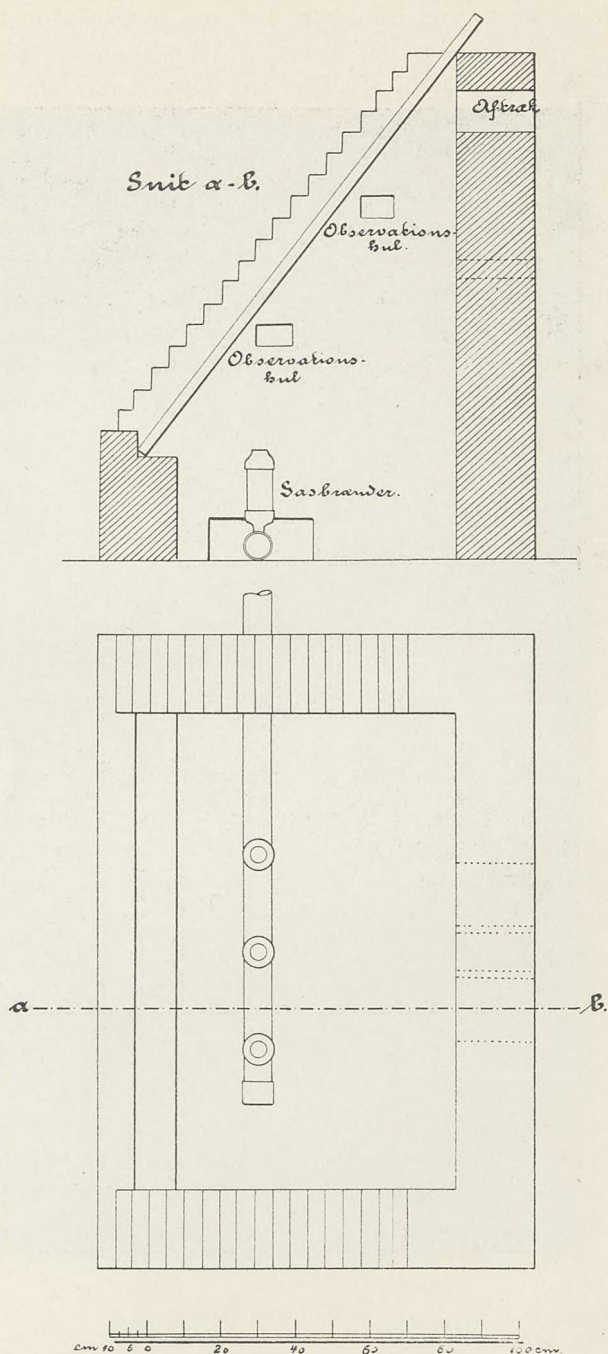


Fig. 32.

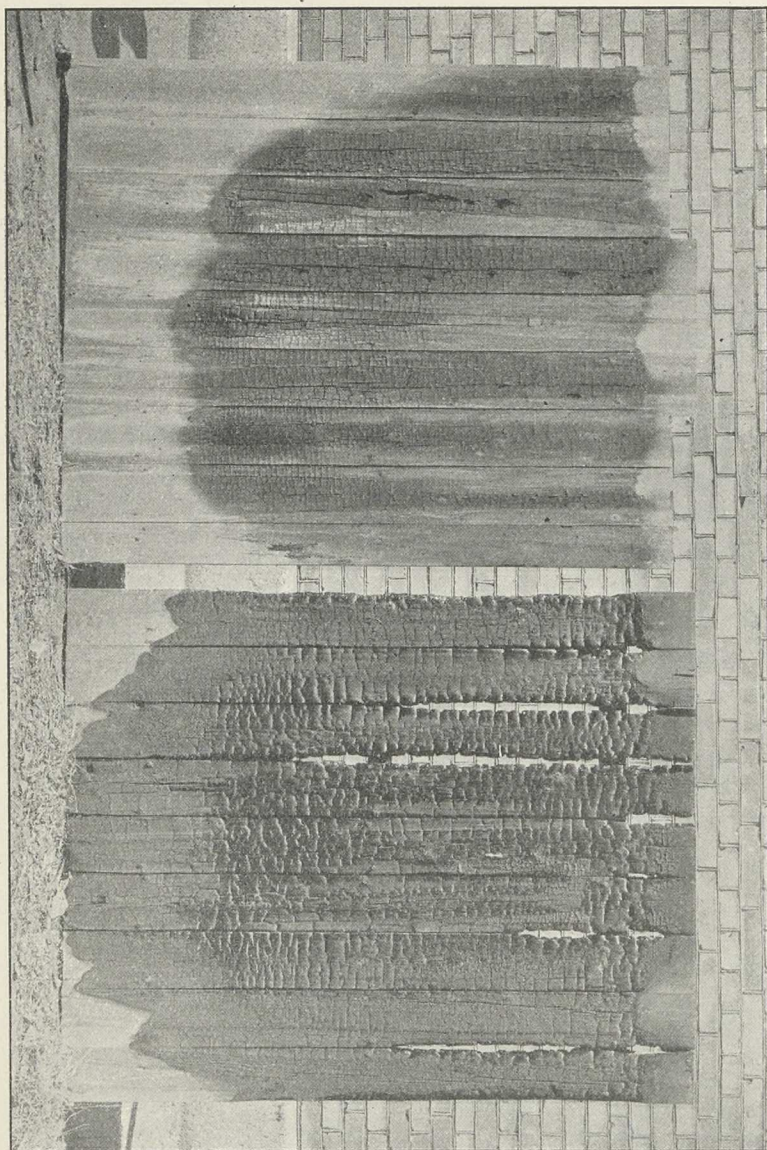


Fig. 33.

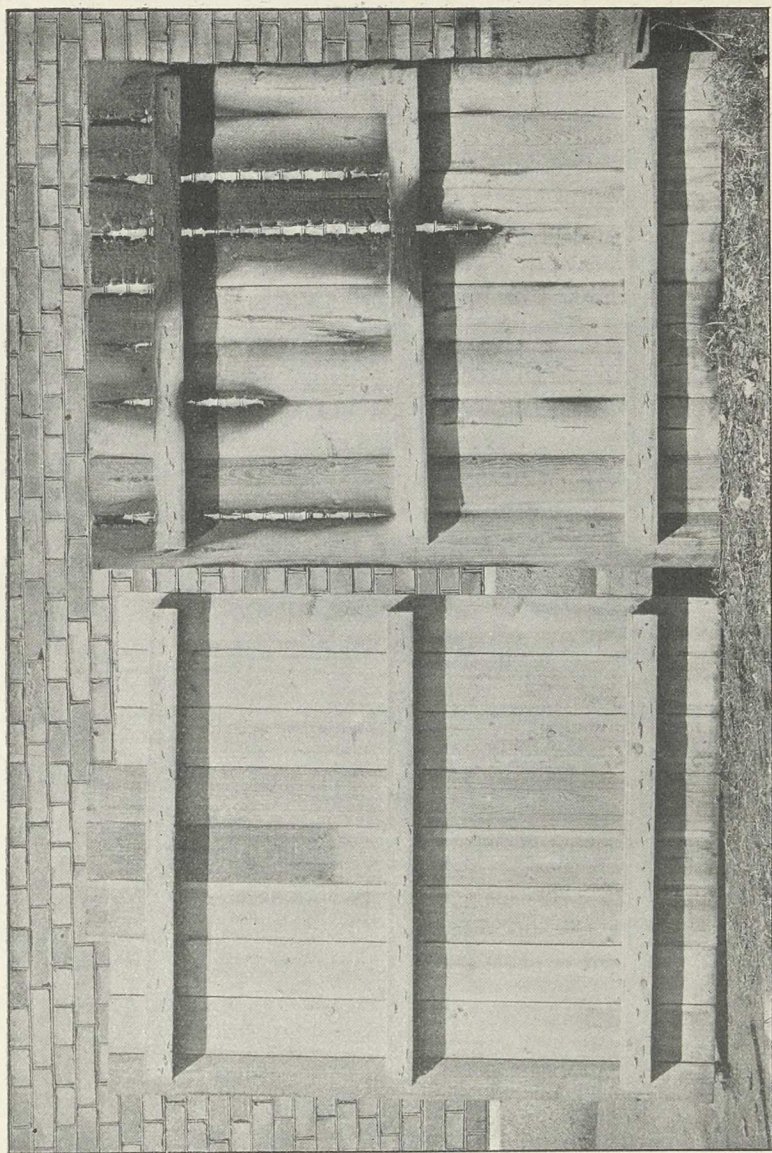


Fig. 34.

gennem det nederste Observationshul hen over de to nærmeste Brændere.

Ved Forsøget iagttoges det, dels naar Flagen var gennembrændt, dels om Træet, efter at Gassen var slukket, brændte videre eller slukkede af sig selv.

Der udførtes ialt 8 Forsøg. Resultatet var i Hovedsagen: 5 imprægnerede Flager brændte igennem paa henholdsvis 18, 20, 20, 46 og 50 Minutter, medens 3 uimprægnerede brændte igennem paa 4 à 14 Minutter. Efter at Gassen var slukket, brændte Træflagerne af det uimprægnerede Træ videre uden at slukkes, medens dette, hvad de 5 Træflager af imprægneret Træ angaar, ikke var Tilfældet for de 3 Træflagers Vedkommende i mere end højst nogle faa Minutter, og for de to's Vedkommende kun var Tilfældet paa enkelte Steder og formentlig navnlig for Brædder af Pitch Pine, hvor disse vare stærkt harpiksholdige.

De foranstaaende Fotografier vise en imprægneret Flade sammenstillet med en uimprægneret efter 1 Kvarters Ildpaavirkning henholdsvis paa Fig. 33 set fra den mod Ilden vendende Side og paa Fig. 34 fra den fra Ilden vendende Side.

Temperaturen under Forsøgene fandtes for de imprægnerede Flager at være ca. 700°, for de uimprægnerede ca. 50° højere, dog maa Temperaturangivelsen betragtes som ret usikker.

m. Prøvning af Linoleum og fugefri Gulvbeklædningsmasser.

I Anstaltens Meddelelse III er der givet Oplysninger ikke blot om Prøvning af Linoleum m. m., men ogsaa om dets Fabrikation og Anvendelse. Den Del af Meddelelsen, der handler om Prøvnin-gen, har været oversat paa Tysk i »Baumaterialienkunde« 1901, S.12.

I denne er der gjort Rede for, at den for Sten almindelige Slidprøvemetode paa en Maskine af *Bauschingers* eller en lignende Konstruktion ikke egner sig for Linoleum.

Man kan nemlig ved denne Metode ved at anvende Smergel som Slidpulver komme til saadanne abnorme og urigtige Resultater, som at Linoleum staar sig bedre mod Slid end Granit, hvilket hidrører fra, at der kan sætte sig noget af Slibepulveret i Linoleumet, saa at dette bliver beklædt paa Overfladen med Smergelpulver, men saa er det i Virkeligheden ikke Linoleumet, der prøves, men et Stof, hvis Overflade for en væsentlig Del bestaar af Smergelpulver.

Ved Anstaltens Metode for Prøvning af Linoleum og fugefri Gulvbeklædningsmasser saasom Papyrolit og lign. mod Slid, føres der en med Sandpapir beklædt Træklods frem og tilbage over Materialet under et vist, let Tryk, og for hver 500 Dobbeltslag skiftes Sandpapiret, der naturligvis maa være af en vis bestemt Finhed, idet det ellers fyldes og forstoppes for meget. Som nærmere omtalt i Anstaltens Meddelelse er det muligt med en ganske ringe Bekostning at omdanne en simpel, amerikansk Koldsavmaskine til Slidprøvemaskine for Linoleum etc. Linoleum opklæbes til Prøven paa et Stk. Spejlglass.

At Metoden ikke er fuldkommen, skal gerne indrømmes, og Geh. Regierungsrat, Prof. Dr. *Martens* har i »Baumaterialienkunde« 1901, Hefte 1—2 fremført nogle Indvendinger imod den, men Manglerne turde dog være mindre end Fordelene, som paavist af Statsprøveanstaltens Direktør i samme Tidsskrift 1901, Hefte 11.

Anstalten har derfor vedblivende anset Prøven for hensigtsmæssig. Hvis Linoleumet er for friskt og derfor for blødt, vil

Tabel XI. Slidprøve med Gulvbeklædningsmateriale.

Vægttabet i % af Prøvelegemets Vægt henført til 4 mm Tykkelse	Linoleum. Antal Sorter	Fugefri Gulv- beklædnings- masser Antal Sorter
indtil 0,10.....		3
fra 0,11—0,20.....	10	1
- 0,21—0,30.....	30	3
- 0,31—0,40.....	24	1
- 0,41—0,50.....	6	3
- 0,51—0,60.....	9	2
- 0,61—0,70.....	2	1
- 0,71—0,80.....	1	4
- 0,81—0,90.....		
- 0,91—1,00.....		3
- 1,01—1,25.....		
- 1,26—1,50.....		1
- 1,51—1,75.....		2
- 1,76—2,00.....		
over 2,01.....		2
Antal Sorter, ialt,...	82	26

Prøven give daarlige Resultater, og haardt Linoleum vil, hvis Bindemidlet er skørt og daarligt, ligeledes give daarlige Resultater. Metoden har da ogsaa vundet Indgang andre Steder, og bruges f. Eks. ved Prøveanstalten i Gøteborg¹⁾ og ved de ungarnske Statsbaner.

I foranstaaende Tabel XI gives en Oversigt over Anstaltens samtlige Resultater indtil den 1. Januar 1909.

n. Prøvning af Genstande af Gummi.

Af saadanne Genstande har Anstalten prøvet forskellige, f. Eks. Gummislanger, Gummipakningsringe og Galochesaaler.

For Slangers Vedkommende er der navnlig gjort kemiske Undersøgelser af Gummien, men ogsaa undertiden Prøver for indvendigt Tryk.

Hvad Gummipakningsringe og andre Pakningsringe angaar, har Anstalten blandt andet gjort Prøver med dem ved at indspænde forskellige Sorter mellem Flanger i et Apparat, hvortil der kunde ledes mættet eller overhødet Damp i længere Tid, og derefter undersøge, dels om de holdt tæt under Forsøget, dels hvorledes deres Tilstand var efter Udtagning af Apparatet. I Anstaltens Meddelelse II er der givet Oplysning om en Variation af denne Metode.

Naturligvis giver en saadan Metode ikke bestemt Underretning om, hvorledes Pakningerne ville holde sig under Brugen, men kun nogen Besked. Fig. 35 viser tilvenstre fire, forskellige, nye Pakningsringe, medens de ses tilhøjre, efter at have været underkastede samme Behandling i et Apparat som det i Meddelelse II anførte, og man vil se, hvor højst uens forskellige Pakningsringe taale den samme Behandling. Denne Afbildning har ikke været offentliggjort tidligere.

Hvad Prøvningen af Galochesaaler mod Slid angaar, har Anstalten dertil — som meddelt i »Baumaterialienkunde« 1905, Hefte 11—12 — anvendt en lignende Fremgangsmaade som ved Linoleumprøvningen. Da der af Galochesaaler kun kan faas mindre Stykker, kan man ikke uden videre befæste disse paa Spejlglaspladen i Linoleumets Sted, idet de ikke ville afgive Styr

¹⁾ I Gøteborg er Metoden funden hensigtsmæssigere end Anvendelsen af *Bauschingers* Maskine, se »Baumaterialienkunde« 1904, Hefte 23.

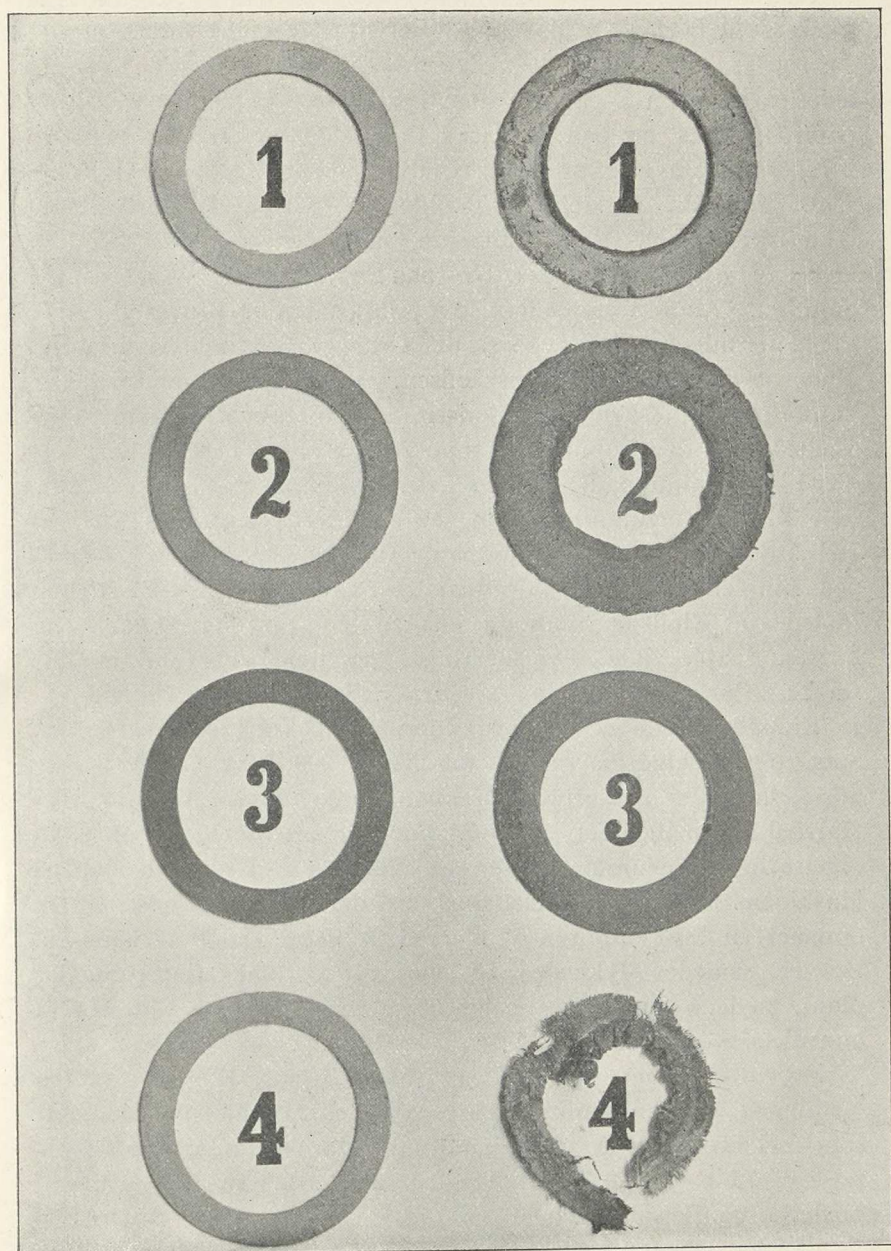


Fig. 35.

nok for den frem- og tilbage vandrende, sandpapirbeklædte Træklods, som derfor vil give sig til at vakle frem og tilbage under Bevægelsen, Fremgangsmaaden er derfor bleven modificeret saaledes, at der om Spejlglaspladen lægges et Stykke Carborundumpapir, medens der paa Klodsens Underside for Enderne befæstes 2 rektangulære Prøvestykker, nemlig 1 udtaget af hver Galochesaal. For ikke at ødelægge Træklodsens, klæbes Prøvestykkerne ikke direkte paa dens Underside, men der er under Klodsens fastskruet Aluminiumplader, hvorpaa Prøvestykkerne klæbes med Solution. Aluminiumpladerne rage lidt udenfor Prøvestykkerne, saa at der udenfor disse er Plads til de Skruer, hvormed Aluminiumpladerne ere fæstede til Træklodsens. Ved at Aluminiumpladerne kunne paa- og afskrues Træklodsens, medens Prøvestykkerne sidde klæbede paa dem, opnaas, at man før og efter Forsøget kan veje alene Aluminiumpladerne med Prøvestykkerne paa uden at veje hele Klodsens med, altsaa veje paa en finere Vægt. Da Klodsens ved Anvendelse af grovt Sandpapir vandrede langt uroligere end ved Linoleumprøvningen formedelst Prøvestykkernes Elasticitet, saaledes at Klodsens vandrede i smaa Hop, og da Sliddet paa fint Sandpapir vilde blive for ringe, benyttes Carborundumpapir fra The Carborundum Co., Niagara Falls. N. Y. Nr. 70 grain.

Endvidere skiftes Carborundumpapiret kun for hvert 1000 Slag, og Træklodsens vendes for hvert 200 Slag. Dette sidste gøres, fordi der af Carborundumpapir anvendes et Ark om hver Halvdel af Spejlglasset. Endelig har der maattet gøres den Afvigelse fra Linoleumforsøgene, at Slaglængden er sat ned, medens Maskinens Omdrejningshastighed er den samme, hvorved er opnaaet en langsommere og derved roligere Gang af Klodsens. Det er saaledes lykkedes at naa til at slide Galochesaaler plant, medens man ved urolig Gang faar Fladerne slidt stærkt konvekse.

Prøvestykkernes Størrelse er $7,5 \times 5,0$ cm. Klodsens og Belastningen er den samme, som anvendtes til Linoleumforsøgene som forklaret i førnævnte Afhandling. Aluminiumpladernes Størrelse er $7,5 \times 9,5 \times 0,4$ cm. Vægten af Klodsens med Aluminiumpladerne og Belastningen er 3,61 kg.

I nedenstaaende Tabel XII ses Resultater fra Anstaltens Forsøg indtil den 1. August 1909. r og l betegne, at et Prøvestykke er henholdsvis fra en Højre- eller Venstresaal, r_1 og r_2 , at det er to Prøvestykker fra samme Højresaal.

Tabel XII. Slidprøver med Galochesaaler.

Galoernes Mærke	Prøvestykkets Mærke	Antal af Dobbelt- slag	Prøve- stykkets Areal i cm ²	Prøve- stykkets Vægttab i g	Vægttab i g pr. cm ²	Anmærkninger
A	1 r ₁	0—2000	36,4	1,50	0,041	} Furerne i Saalen bleve ikke slidte fuldstændig af ved de 2000 Slag.
	1 r ₂	0—2000	38,0	1,51	0,040	
	1 r ₁	2—4000	36,4	0,82	0,023	} Furerne i Saalen vare endnu ikke slidte fuldstændig af.
	1 r ₂	2—4000	38,0	0,91	0,024	
B	2 r ₁	0—2000	40,5	2,45	0,060	} Furerne i Saalen vare slidte af efter de første 2000 Slag.
	2 r ₂	0—2000	39,0	2,26	0,058	
	2 r ₁	2—4000	40,5	2,47	0,061	
	2 r ₂	2—4000	39,0	2,25	0,058	
C	3 r	0—2000	37,5	1,15	0,031	} Furerne i Saalen bleve ikke slidte fuldstændig af ved de 2000 Slag.
	3 l	0—2000	37,5	0,98	0,026	
	3 r	2—4000	37,5	0,73	0,019	} Furerne i Saalen vare endnu ikke slidte fuldstændig af.
	3 l	2—4000	37,5	0,72	0,019	
D	4 r	0—2000	37,5	0,90	0,024	} Furerne i Saalen bleve ikke slidte fuldstændig af ved de 2000 Slag.
	4 l	0—2000	37,5	0,85	0,023	
	4 r	2—4000	37,5	0,75	0,020	} Furerne i Saalen vare endnu ikke slidte fuldstændig af.
	4 l	2—4000	37,5	0,64	0,017	
E	5 r	0—2000	37,5	1,39	0,037	} Furerne i Saalen vare slidte af efter de første 2000 Slag.
	5 l	0—2000	37,5	2,02	0,054	
	5 r	2—4000	37,5	1,91	0,051	
	5 l	2—4000	37,5	2,20	0,059	
F	6 r	0—2000	37,5	2,15	0,057	} Furerne i Saalen vare slidte af efter de første 2000 Slag.
	6 l	0—2000	37,5	1,25	0,033	
	6 r	2—4000	37,5	2,38	0,063	
	6 l	2—4000	37,5	3,33	0,089	
G	7 r	0—2000	37,5	2,44	0,065	} Furerne i Saalen vare slidte af efter de første 2000 Slag.
	7 l	0—2000	37,5	2,48	0,066	
	7 r	2—4000	37,5	1,74	0,046	
	7 l	2—4000	37,5	1,73	0,046	
H	8 r	0—2000	37,5	1,23	0,033	} Furerne i Saalen bleve ikke slidte af ved de første 2000 Slag.
	8 l	0—2000	37,5	1,08	0,029	
	8 r	2—4000	37,5	0,75	0,020	} Furerne i Saalen vare endnu ikke slidte fuldstændig af.
	8 l	2—4000	37,5	0,61	0,016	
	9 r	0—2000	56,2	1,77	0,031	
	9 l	0—2000	56,2	1,80	0,032	
	9 r	2—4000	56,2	1,89	0,034	
	9 l	2—4000	56,2	2,10	0,037	
	10 r	0—2000	55,5	1,72	0,031	
	10 l	0—2000	55,5	1,62	0,029	
	10 r	2—4000	55,5	0,55	0,010	
	10 l	2—4000	55,5	0,60	0,011	

I Stedet for at prøve paa nævnte Maade et Prøvestykke af hver Saal i et Par Galocher, kan man naturligvis lade hvert af Prøvestykkerne hidrøre fra en Saal i 2 forskellige Slags Galocher.

Af Vægttabet, Vægten af Prøvestykket og Materialets Vægtfylde lader det bortslebne Volumen sig naturligvis beregne.

o. Forskellige Undersøgelser.

I Aarenes Løb er der naturligvis ved Statsprøveanstalten gjort en stor Del Undersøgelser ud over de hidtil anførte. Nogle af disse skulle nævnes her.

Der er saaledes gjort de almindelige Undersøgelser over Papir, Garn og Tøjer. Da Anstalten til Prøvning af Garn og Tøjer kun er daarlig udrustet, har man maattet hjælpe sig paa bedste Maade. Saaledes er det paa S. 78, Fig. 28 viste Apparat til Adhæsiionsforsøg blevet anvendt til Prøvning af Styrken af Bindegarn til Mejemaskiner, idet Garnets ene Ende blev fæstet til Dynamometret M, medens dets anden Ende vikledes om Akslen A.

En enkelt Gang har Anstalten prøvet at undersøge Tøj for Slid ved at bestemme, hvilken Slags Tøj iblandt flere fremsendte, der ved Slid kunde antages at fnugge mindst, idet Tøjet skulde anvendes af Damer, der betjente fine Apparater, hvori der kom Forstyrrelse, naar der fløj Fnug op i dem. Af de forskellige Sorter Tøj afklippedes da ens firkantede Stykker, hvis ene, smalle Kant fæstedes langs Frembringere paa en Tromle i samme, indbyrdes Afstand. Nær Tromlen blev der stillet et skraat Brædt, beklædt med Sandpapir, saaledes at ved Tromlens Rotation de flagrende Tøjstykker bleve slæbte paa samme Vis nedad Sandpapirfladen og derved slidte. Man bedømte bagefter Sorternes Udseende. Om end Prøven langt fra var god, gav den dog nogen Oplysning, og den var jo meget simpel og billig at anstille.

Til Undersøgelse af Isoleringsmaterialier for Damp rør har Anstalten benyttet en Installation, der i det væsentlige er den samme som den, der findes i Prøveanstalten i Gøteborg og er beskrevet paa nedenfor nævnte Sted¹⁾.

Til Undersøgelse af Gasglødenet mod Rystelser, har Anstalten ladet forfærdige et Apparat som vist i Fig. 36 ved en temmelig simpel Tilføjelse til et *Böhmes* Hammerapparat af ældre Konstruktion²⁾.

¹⁾ Svensk tekn. Tidsskrift 1901.

²⁾ Anstaltens Aarsberetning for 1903.

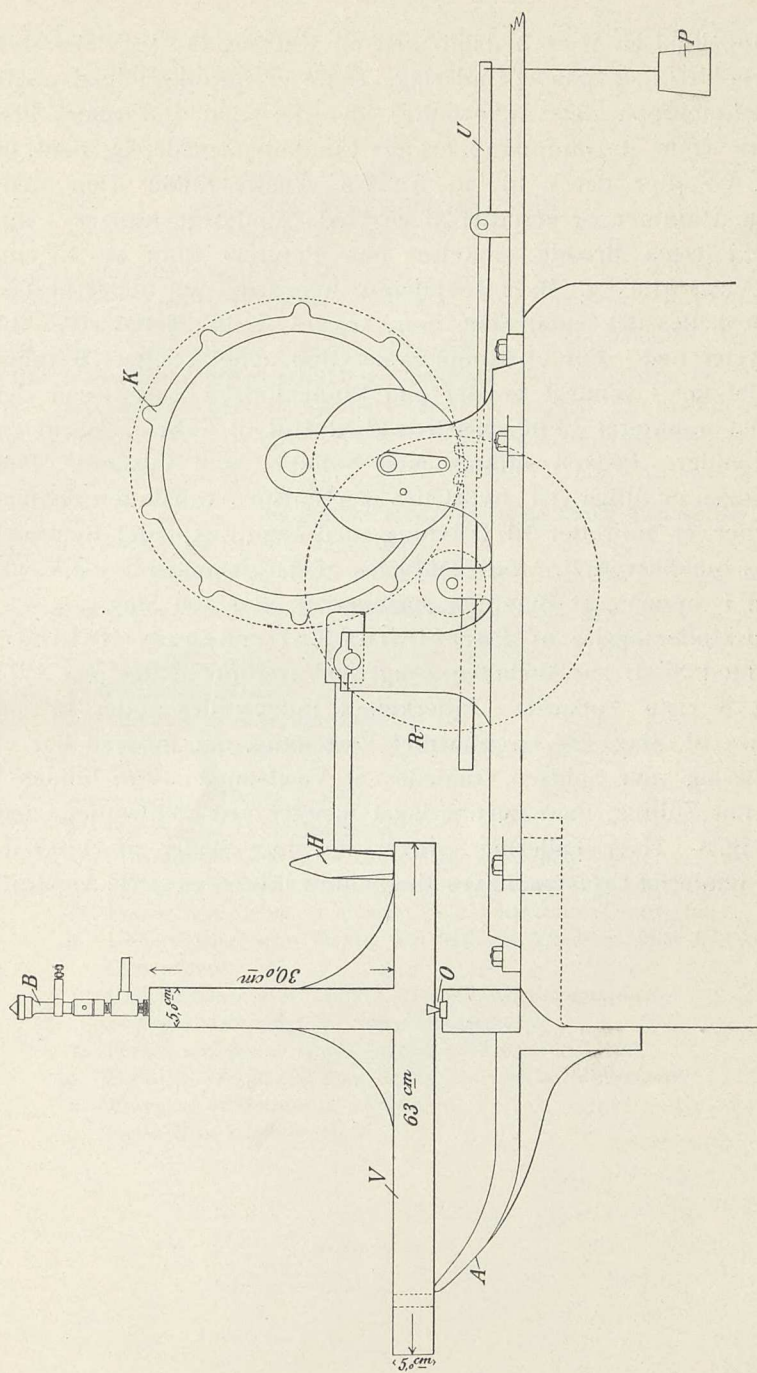


Fig. 36.

Vippeklodsen V er henlagt med en Knivseg O, der deler den i Forholdet 1 : 2, paa et Underlag. Dette er forankret med nogle af Hammerapparatets Ankerbolte, idet det naar ind under den venstre Ende af Hammerapparatets Fundamentplade, og med sit Horn A støtter det V 16 cm fra V's venstre Ende. Den sædvanlige Hammer er erstattet af en, hvis Faldvægt kun er 1 kg. Vippeklodsens Bredde vinkelret paa Papirets Plan er 15 cm, dens Vægt 51,5 kg. B er Brænderen, hvorpaa Glødenettet fæstes, og der tælles det Antal Slag, som kræves, indtil Nettet rives itu og styrter ned. For at kunne ryste Glødenettet i lodret Retning i Stedet for i vandret er der paa Vippeklodsen ogsaa paa det med en punkteret Linie antydede Sted Hul til Anbringelse af en Gasbrænder. Prøven udføres med Nettet i kold Tilstand. Paa Tegningen er tillige vist, hvorledes paa Statsprøveanstalten *Bøhmes* Hammer er indrettet til Drivning med Remtræk, idet Remmen lægges om Skiven R. Ved Tilføjelse af Vægtstangen U og Vægtloddet P opnaas, at Remmen springer af efter 150 Slag.

Til Undersøgelse af Porcellains-Tallerkeners Holdbarhed mod Stød, har Anstalten brugt en Variation af det paa S. 25 i Fig. 8 viste Apparat. Tallerkenen indspændes under 45° og rammes af Slag fra en enarmet Vægtstang, der foroven har et Jærnbslag nær Spidsen, saaledes at Vægtstangen kan holdes i en skraa Stilling, naar Jærnbslaget hænger ved Elektromagneten E i Fig. 8. Hver Tallerken prøves paa flere Steder af Omkredsen. Synderlig Erfaring haves dog endnu ikke med dette Apparat.

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ON THE DEVELOPMENT OF TESTING OF MATERIALS
IN THE NORTH
AND
ON THE WORK OF THE DANISH STATES TESTING
LABORATORY IN COPENHAGEN.

(ENGLISH TRANSLATION.)

A. The Development of Methods of Testing Materials in the North.

At the International congress for testing materials which the French government held in Paris during the universal exhibition in 1900 there was presented a rather great and richly illustrated work of Mr. *Frémont*, the high esteemed civil engineer, about the development of testing materials¹⁾. With Mr. *Frémont's* permission an abstract of this was rendered in the periodical of the Danish Society of civil Engineers »Ingeniøren«²⁾ in an essay by Professor *Hannover*, the undersigned director of the States Testing Laboratory in Copenhagen, who at the same time carried on the history of the testing of materials up to the present.

In this essay there was of course not much space left for mentioning the development in the North which taken together with the general development has been of only little importance.

But on this opportunity where technical men from all countries are gathered in Denmark there might however be some reason to show what share the North especially Denmark has in the development of testing materials.

I. Poul Würtz.

In the above-mentioned splendid work of *Frémont* it is stated, quoting *P. S. Girard: Traité analytique de la résistance des solides*,

¹⁾ Évolution des méthodes et des appareils employés pour l'essai des matériaux de construction.

²⁾ »Ingeniøren« 1908, S. 167.

etc. 1798, that *Galileo* was the first who tried to utilize the laws of mechanics on the resisting power of solids. When *Galileo* visited the Arsenal in Venice, he saw in the different workshops the machines they constructed, and from that time he began pondering upon this power of resistance. *Galileo* easily perceived that a cylinder when suspended perpendicularly would draw itself over at the weakest spot and further¹⁾ that it would be influenced quite differently if it was placed horizontally with one end in a wall. He made a formula, although not quite correct, of the strains it would be subjected to in the cross-section which lies in the plane of the wall. He further found that a rectangular beam was stronger when placed on edge than when on the flat. He also took to calculate how a beam fixed in one end should be formed to contain as little material as possible in the different cross-sections and found out that the underside being horizontal the topside ought to be formed after a parabola.

Frémont further points out that *Galileo*, who died on the 8th of January 1642, 77 years old, and who never omitted to call people's attention to the practical use of the results he arrived to, did not however make real experiments of testing materials. *Frémont* writes, quoting *Girard*, that the first experiments seem to be due to a Swede *P. Wurtzius* as it appears from a letter to him in 1657 from *François Blondel* the French architect, who after *Galileo* is the first author who writes about these matters and who says himself that he was one of the last of *Galileo's* pupils²⁾.

Through the publication of *Leonardo da Vinci's* large, hitherto unpublished, manuscript »Codice atlantico³⁾, which dates from about 1500, it appears however, that already *Leonardo* has made experiments on strength, *Galileo*, thus, not being the first who has written about such experiments, and *Wurtzius* not the first who has executed such experiments. But *Leonardo's* experiments which for instance treated of the deflection of beams when subjected to different loads, have hardly gone so far as to practically test the accuracy of the strength-calculations, or to employ them practically.

¹⁾ From *Galileo's* most celebrated work on mechanics: *Discorsi e dimostrazioni matematiche* etc. 1638.

²⁾ The undermentioned letter from *Blondel* to *Sieur B.* pag. 166.

³⁾ See Prof. *Th. Beck's* treatise in *Zeitschr. des Ver. deutsch. Ing.* 1906, p. 524

As it now, as mentioned, was stated that a Swede *P. Wurtzius* was the first practical tester of materials I asked *Dr. Benedicks*, the well-known physicist at the physical institute of the university of Upsala to try to procure some more detailed informations about his supposed compatriot *P. Wurtzius*. In the treatise of *Frémont* there are references to *Girard's* work, mentioned above, and to the fact that the letter from *Blondel* is quoted in »Recueil de plusieurs traités de mathématiques par quelques membres de l'Academie des sciences« in folio 1676 which however appeared not to be correct, — (see page 110, Note 1 hereafter).

In November 1908 I got an answer from *Dr. Benedicks* from which it appears that he had found out that as far as he could judge *P. Wurtzius* was the same as the commander Baron *Poul Würtz* (v. Wirtz) one of the most renowned commanders of the swedish army. But at the same time it appeared that *P. Wurtzius* was not a native of Sweden but was borne on the 30th of October 1612 at Husum in Sleswic which at that time was Danish.

At the same time *Dr. Benedicks* was kind enough to give me some informations about *Würtz's* life taken from »Svensk biogr. Lexikon« (Swedish Biographical Dictionary) and »Nord. Familjebok« and to inform me that a biography of him: »Leben und Thaten des Herrn *Paulus v. Wirtzen* by *Philander v. d. Weistritz* (Pseudonym for *Christ. Gottl. Menzel*) was published in Copenhagen and Leipzig 1756¹⁾ (translated from a Dutch original biography from 1681). Further *Dr. Benedicks* advised to examine the works of *Blondel*: »Manière de fortifier les places« 1683 and »L'art de jeter les bombes« 1685, upon which subjects *Blondel* might have corresponded, with some result, with *Würtz*¹⁾.

As it thus seemed very likely that the first who had practised testing of materials was a native Dane I asked *Dr. J. A. Fridericia*, Prof. of the University of Copenhagen, to assist me in closer examining the correctness of this; and he did so with great readiness.

At the University-Library Prof. *Fridericia* soon found in *Mémoires de l'Academie royale des Sciences* 1666—99, T. 5 (Paris 1729, 4to) a series of essays by *Blondel* under the general

¹⁾ Ref. Allgemeine deutsche Biographie XLIV.

²⁾ At any rate there is nothing about it in the first of these treatises.

title: Resolution des quatre principaux problèmes d'architecture. The fourth problem is herein called: Trouver la ligne sur laquelle les poutres doivent être coupées en leur hauteur et largeur pour les rendre partout également fortes et résistantes.

The first part of it is called: Premier discours ou *F. B. epistola ad P. W.*¹⁾, in qua celebris Galilæi propositio discutitur circa naturam . . . , which means: »*F. B.*'s letter to *P. W.*, in which is discussed *Galileo*'s celebrated sentence about the form of the line after which beams are to be fashioned so as to be all over of the same power of resistance, and in which it is proved that the mentioned line is not parabolic as *Galileo* thought but elliptic«.

In this treatise we find page 478:

»Perjucunda mihi profecto fuit elegantissima narratio de ad-
»mirabili illa machina qua in Colossicoteri tui Leonis Hyperborei
»constructione uti te dicis, et magnopere me delectat ista con-
»templatio intricatissimæ illius tignorum, rudentum et ferramen-
»torum compagis quæ rectoris imperio ingenioque ita se præstat
»obsequentem«.

At the translation of this the word »Colossicoterum« gives some difficulties. But of the following it seems however to appear that the matter in question is ship-building and possibly the word may mean the hull and »Leo hyperboreus« i. e. the northern Lion, may be the name of a ship. In that case the translation would run:

»Your elegant narration about the remarkable machine which
»you say you are using at the construction of the hull »of the
»The Northern Lion« was in truth very agreeable to me and I
»was highly delighted at the contemplation of the very intri-
»cated joining of beams, ropes, and ironwork which prove so
»obsequious to the director's orders and genius«.

Further we find page 478:

Quod autem scribis, sectas a te ex præscripto Galilæi linea
»parabolica secundum altitudinem trabes, ut æqualis ubique

¹⁾ This letter is dated 1657, pridie Idus Sextilis, 12. August. When *Poggendorf* in his *Wörterbuch* vol. 1 under *Blondel* states an article of him: Sur la résistance des solides in *Mem.* Par. T. 1 (surely to be understood as *Mémoires de l'Académie de Paris*) this must to *Fridericia*'s opinion be wrong, as such an article is not to be found in T. 1 but in T. 5.

»forent resistentiæ, non omnino expectationi tuæ respondisse ...«, which means:

»What you write that the beams formed by you according to the prescriptions of *Galileo* after a parabola in height dont answer to your expectations about their being all over of the same power of resistance . . .«

Blondel continues saying that to begin with he wondered very much at this but that he had now found out that *Galileo* was wrong.

Page 486 he writes:

»Atque ex istis omnibus patet ratio cur nimiam quam in *Galilæum* habebas fiduciam experimenta tua deluserunt«, which means:

»From all this it appears why your experiments have disappointed your too great confidence in *Galileo*«.

This is as far as known the first place in any literature where there is spoken about experiments on testing of materials.

Page 493 *Blondel* writes:

»Etiam atque etiam te rogo ad me quam primum rescribe quid sentias factis præsertim, ea qua soles sedulitate atque solertia experimentis«.

Here *Blondel* writes again about *P. W.*'s experiments, the meaning being:

»Again and again I beg you to write as soon as possible to me, what you think and especially when you with your usual diligence and aptness have made experiments«.

The question is now: Is *P. W.* the celebrated commander *Würtz*?

The name of *Würtz* is not mentioned as we see; but Prof. *Fridericia* takes it for granted that it is he who is meant, for in the introduction to the letter *Blondel* says that he has not been able to answer *P. W.*'s communication as *W.*'s master has flown from the Sarmates (i. e. the Poles) to the Cimbrians¹⁾ which must be an allusion to Karl Gustavs, the king of Sweden's march from Poland to Denmark in July 1657, *Würtz* being in Swedish service during this campaign.

The second part of *Blondel's* »fourth Problem« which is in

¹⁾ Nam a quo tempore a Sarmatis ad Cimbros evolavit Heros vester

French while the first part is in Latin has hardly anything to do with *P. W.* Its title is:

Second Discours ou Lettre au Sr. (Sieur) B. pour la résolution de ses doutes sur les Propositions du premier Discours.

It is dated Paris 18th of July 1661. Moreover *Blondel* says in this letter that he more than 12 years ago wrote a work: *Galilæus Promotus de resistentia Solidorum*, which he however has not yet published.

The letter begins:

Monsieur. Je vous suis parfaitement obligé du soin que vous avez pris, de me donner part des remarques, qui ont esté faites sur une Lettre, que j'écrivis il y a quelques années a un de mes Amis en Suède . . .

Here is evidently the explanation why *Würtz* later on has been supposed to be a Swede.

At the Royal Library in Copenhagen, Prof. *Fridericia* further succeeded in finding a German translation of the book of *Girard* which is mentioned by *Frémont* (catalogue 51 Pag 23) and the name of which is: *P. S. Girard: Analytische Abhdlg. von dem Widerstande fester Körper, und von den Körpern von überall gleichem Widerstande, a. d. Franz. übers., Giessen 1803, 4to.* In the introduction we find on page X:

»Was seine (3: *Galileis*) Hypothese über die Cohärenz der
 »Körper betrifft, so muss hier bemerkt werden, dass er sie durch
 »keine Versuche bestätigt hat. Unter den Schülern, welche in
 »seinen Werken die Elemente einer neuen Wissenschaft studier-
 »ten, hätte sich doch wohl irgend einer finden sollen, der es
 »unternommen hätte, diese Hypothese durch Versuche zu be-
 »gründen, um so mehr, da Galilei es niemals unterliesz, die Nütz-
 »lichkeit seiner Theorie für die mechanischen Künste durch Bei-
 »spiele anschaulich zu machen. Demungeachtet aber wurden die
 »ersten Versuche über den Widerstand fester Körper nicht in
 »Italien angestellt, sondern wir sind sie einem Schweden Nah-
 »mens *P. Wurtzius* schuldig, wie aus dem Briefe hervorgeht, den
 »er 1657¹⁾ an *François Blondel* schrieb. Dieser französische Bau-

¹⁾ Beneath the text we find: Dieser Brief ist in einer von mehreren Mitgliedern der Akad. der Wissensch. veranstalteter Sammlung mathematischer Abhandlungen angeführt (in Folio 1676). With this a before mentioned work: *Recueil de plusieurs traités etc.* is surely meant, but in this Work

»meister war der zweyte, der über diese Materie schrieb. Es scheint, dass er sich nicht sehr geeilt habe seine Entdeckungen bekannt zu machen, denn in einem Briefe an W. vom Jahre 1661¹⁾ sagt er, dass er schon 1649 ein Werk über den Widerstand der festen Körper unter dem Titel: »Galilaeus promotus« geschrieben habe«.

Respecting the life of *Poul Würtz* there are to be found very interesting informations in the Danish Biographical Dictionary vol. 19 Pag. 248. From that we learn how he, who was born in Husum on the 30th of October 1612, was the son of a citizen of that town *Claus W.* and *Margrethe Busch*. He had a burning love of knowledge and great energy and having been engaged as a clerk at a lawyer in Sleswic he used all his spare time to satisfy his thirst of knowledge. Further, how fortune was kind to him: he met an imperial Austrian captain, sent to the Gottorpien court, who took a liking to him and took him to Vienna where he was to be educated by the Jesuits. But *Würtz's* mind was bent upon the military profession and he therefore enlisted as a common soldier and soon advanced to lieutenant; but to be more easily promoted he entered the Swedish army where he made a powerful friend and protector in Karl Gustav of Zweibrücken — afterwards Karl X, King of Sweden — who knew to value his ingenuity, his courage, and his presence of mind and who raised him from rank to rank, so that he at the end of the Thirty-year's-war was a colonel and the chief of the Swedish Horseguards. There are a good deal of particulars about his partaking of Karl Gustav's wars in Poland after which he was appointed Generallieutenant and baron and enfeoffed the estate of Ørnholm in »Kexholm Len« (county of Kexholm) and appointed the governor of Stettin. His corps marched through Holsten and Sleswic and partook of the assault on Frederiksdode on the 24th of October 1657. Having later on felt himself neglected in Sweden he went to Hamburg to live there as a private

which is to be found at the University Library of Copenhagen there is no mentioning of *Blondel* or *Würtz*.

Girard who seems to have been the source of *Frémonts* informations of *Würtz* seems to have made a mistake in his above quoted passage on page X of the introduction, probably in not noticing that *Blondel's* letters of 1657 and 1661 which are mentioned above are to two different persons.

¹⁾ Beneath the text we find: *F. B. epistola ad P. W. in qua famosa Galilaei propositio discutitur circa naturam . . .*

person, but accepted an invitation to enter the service of his native-country and in January 1665 he was appointed field-marshal and in July general-governor of the duchies and principalities of Denmark. But in the long run a warrior who had become grizzled on the battlefield could not feel satisfied at the easy life of such a peaceful time and having obtained discharge from Danish service October 31st 1665 he entered Dutch service. In 1674 he retired to private life and died in Hamburg the night between the 23rd and 24th of March 1676.

In *Müller's Pinakothek* vol. XII page 104 (Royal Library) we find the portrait of Würtz. It is rendered on the frontispiece (fig. 1).

The Danish States testing Laboratory has wished to begin this essay on »the development of the testing of materials in the North« with drawing away the veil of oblivion from the fact that our native-country has the honour of having given birth to the man who, as far as known, was the first to make experiments on testing of materials for practical purposes.

Poul Würtz, whose life otherwise especially belongs to Sweden, ought to be looked upon as one of the greatest men of the North.

II. The Development of the Testing of Materials in Sweden.

In the 18th and 19th centuries it is especially Sweden which among the northern countries has the honour of having attributed to the development of the testing of materials while in Norway and Finland it has been of less importance.

In his book »*De Ferro*« 1734 *Swedenborg* describes several experiments, for instance bending experiments, which the merchants made when buying Swedish iron.

In 1826 Mr. *P. Lagerhjelm*, a Swedish Judge, occasioned comparative experiments on forged and rolled ironbars. The results of the experiments were in 1827 published in the annals of the swedish »*Järnkontor*«.

Of later experiments some of the most important are probably the examinations of railway-materials which *Knut Styffe*¹⁾

¹⁾ *Knut Styffe*: Om jerns og ståls elasticitet, tånjbarhet och absoluta styrka, Stockholm 1866.

made in the 60ies before a committee probably established because a railway carriage in which King Karl XV happened to be, had run off the rails because of a break on a wheel-tire. *Knut Styffe* who ended as chief-director at the royal polytechnical Institute in Stockholm 1897 and who on the international congress for testing materials in Stockholm by its president, Prof. *v. Tetmajer*, was hailed as »the Nestor of the testing of materials whose experiments are now classic«, found among other things by his experiments that the many breaks on wheel-tires and rails during the winter for a great part are due to the stiffness of the frozen ground.

Of later Swedish researches are especially to be mentioned *Brinell's* celebrated researches on the changes in the structure of steel by heating and cooling and his at present so much mentioned test of hardness, *Wijkander's* researches on the strength of wood, *Sellergren's* impact tests and testing of edge tools, *Svedelius'*, *Wahlberg's* and *Braune's* tests of iron and steel, Dr. *Benedick's* micrographical researches etc. etc.

An interesting account of Sweden's part in the development of testing of materials was given on the international congress for testing materials, »Hållfasthetskongressen« in Stockholm in 1897 in the introduction to the work published by »Jern-Kontoret«: *Festigkeitsproben schwedischer Materialien*, Stockholm 1897, (also in Swedish: *Hållfasthetsprof å svenska Materialier i. e. testing of swedish materials*).

Sweden has now, as known, two testing-laboratories: one at the royal polytechnical Institute in Stockholm and another at the Chalmersska Institute in Gothenburg.

III. The Development of the Testing of Materials in Denmark.

In Denmark it is, as far as known, *Jens Kraft* who first wrote at length about testing of materials, in the second volume of his great »*Mekanik*« 1764¹⁾.

But the testing of materials had already earlier than that found its way to this country. In *Carl Bruun*: Copenhagen (Kjøbenhavn) III, 1901, p. 48 is mentioned how an »*anchor-te*

¹⁾ For closer information see »*Ingeniøren*« 1908 p. 186.

sting-machine« had been raised in 1761 in Copenhagen at »Gammelstrand« opposite to »Naboløs«. It consisted of a post of thirty feet from which the anchors by their own weight should fall down on an underlying cannon without being damaged. To the test and the following stamping which of course did not pass without expenses the anchor-smiths opposed very much. They directly refused to part with their anchors if they had to be stamped or continued selling unstamped anchors. In 1764 Christen Jochumsen Lund, an anchor-smith, was fined 1,000 Rdlr. (more than 100 £) for this trespass (he was however spared from paying more than 100 Rdlr.); and on that occasion it was found out that even the Asiatic Company never had its anchors tested nor stamped.

To obtain a total view of what Denmark has contributed to the development of the testing of materials, I adressed myself to the Engineer Corps, to the State Railways, to the director of the Technical Service of the Artillery, to the Royal Navy-Yard and to the Government's Technical Office for Testing of Paper and asked these institutions to assist the States Testing Laboratory with informations. Thanking these institutions for their readiness I render the received informations and some other informations especially about the Danish States Testing Laboratory.

a. Account of Experiments made by the Engineer Corps during the years 1858—1880 on Portland-cement and Concrete¹⁾.

When at the beginning of the last century the engineers began using brick-constructions for the sea-forts at Copenhagen the officers of the Royal Engineers who directed the work had to make experiments before deciding how the mortar, exposed to the violating influence of the sea, should be composed in the most appropriate way. From the year 1845 they commenced complete series of experiments on various sorts of hydraulic mortar. These experiments were made by making test-pieces of different proportions which after their setting were put out into the sea where they were under observation for a series of years.

When the engineer corps in 1854 entrusted Mr. *J. F. M. Ernst*, at that time a captain (born in Copenhagen 1820, dead

¹⁾ By *L. Madsen*, captain of the Royal Engineers.

1897 as general (see fig. 2, page 10), with the drawing up of a proposal of enlarging the existing maritime fortifications of Copenhagen the captain recommenced the earlier series of experiments on an enlarged scale and introduced especially the Portland-cement into the experiments.

From the 15th of April 1858 tensile tests with mortar-briquettes were also commenced.

By these preparatory experiments the attention was called to the good qualities of the Portland-cement and as, besides, a certain fear arose that the pile-worms should too rapidly destroy the wood-construction in the foundation of the maritime forts the quay-wall in the harbour of fort »Prøvesten« was made as a wall of blocks founded of Portland-cement-concrete with broken stones of granite.

Having made sufficient experiments they had from the very beginning succeeded in making the concrete in the proper way both respecting proportions and mixing and ramming of the mixture; and therefore the blocks showed such a strength during the transport and the placing that captain *Ernst* proposed to the Engineer Corps to try how far concrete would show greater power of resistance against cannonade than the masonry of bricks in lime-cement-mortar or of cleaved stones of granite in cement-mortar, which were meant to be used at the building of the fort.

For that reason there was made shooting-tests on masonry of the above-mentioned kinds, and the concrete proved to possess a far greater elasticity and cohesive power than the other kinds of masonry (Description of the experiments are to be found in »Oversigt over Artilleriets Forsøg II«, 1866). It was therefore resolved to make the forts entirely of concrete; and this material was afterwards used in the other maritime forts and in the provisory redoubts at Dybbøl — although to less extent, of regard to the expenses.

In spite of this method being made known to foreign countries (see for instance the fifty years' jubilee-treatise of the Portland-cement-factory of Stettin) it was adopted nowhere else, before the development of the artillery about 20 years after forced the countries to leave the earlier masonry-materials and adopt the Portland-cement-concrete as the chief-material in the military-engineering.

By the building of the new sea-forts and the strengthening

of the old there was used a considerable amount of cement which was provided from several German, English and later on also from Danish factories. Already from the year 1858 every ship-load was carefully tested with regard to setting-time, constancy of volume, weight pro litre and strength.

The tests of strength during the years 1859—1867 were chiefly tensile tests. Already in 1860 compression-tests were begun, and from 1867 such tests were made side by side with the tensile tests. There was used test-pieces of neat cement and of mortar in different proportions and the tests were extended to 1 à 2 years for each supply so that a good knowledge of the rate of hardening was obtained.

In the years from 1858—1873 the tests were made under the direction of Mr. A. J. C. *Keyper* who is now a colonel (born 1833, see fig. 3, page 12). He has given a description of the experiments and their results in »Maanedsskrift for tekniske Meddelelser, udgivet af Industriforeningen i Kjøbenhavn« (Monthly Review for technical informations, published by »Industriforeningen in Copenhagen«) 8th annual 1873.

From 1876—1880 the experiments were made by Mr. A. F. C. *Andersen* at that time a lieutenant (born 1848, dead 1892 as captain, — see fig. 4, page 13) who partly improved the old methods, partly constructed new testing apparatus. The results of his works are to be found in »Den tekniske Forenings Tidsskrift« (Journal of the Technical Society) 1877—78 and 1880—81. It is due to him that already in the earliest Danish specifications for testing of cement (1878) prescriptions are given for the time which by the tensile tests has to pass between the beginning of the test and the fracture.

In the Danish specifications for testing of cement of 1889 there was fixed greater dimensions for test-pieces for compression tests than those which hitherto were used by the engineer corps. As the Engineer Corps's testing laboratory on »Kvintus« was not furnished with testing machines suitable for these its later results are of value only for its own service.

The earliest works of the laboratory are of importance because of having led to a proper choice of building-materials for constructions of great pecuniar interest. The following works had a certain influence on the development of the cement-manufacturing having at an early time incited the factories to produce the best

possible material so as to meet all demands of the Danish Engineer Corps. They are all in all an instance of the practical value of the testing of materials.

b. Account of the Testing of Materials at the Danish State Railways.

At the railway-division rails and connecting-materials, structural-steel and cement are tested after usual standards.

At the machine division the following tests are made¹⁾:

Caoutchouc. Determination of ash. Test of constituents soluble in 5 % alcoholic sodium-hydrate. Influence of heating in steam at 5—15 Atm. Influence of rapid cooling. Bending tests with heating-tubes.

Coal. Determination of ash, sulphur and volatile constituents. Determination of calorific-value.

Oils. Determination of specific gravity, flash-point, burning-point, content of acid, power of absorption at low temperatures and other properties at temperatures below 0°. Determination of asphalt, evaporation at temperatures near the flash-point and the resulting increase in asphalt.

Iron and steel. Testing of strength, bending tests after or without previous hardening, jumping tests, punching-tests and welding-tests.

Plate- and evolute-springs. Test of elasticity.

Other metals. Tests of strength. Analyses, partly electrolytic.

Textiles. Tests of strength. Microscopical examinations.

Asbestos- and other packing-materials. Tensile tests. Treatment with high-pressure steam.

Asbestos and Fibres for Isolation. Determination of specific gravity. Determination of the contents of organic substances.

Sulphuric acid for accumulators. Testing of the presence of arsenic and chlorine. Determination of strength.

Distilled water. Testing of the presence of chlorine.

Minium, litharge for accumulators. Determination of strength.

¹⁾ After informations of Mr. Busse, director of the Danish State Railway (mech. department).

nation of insoluble constituents. Determination of oxide of lead. Examination for copper and other heavy metals.

Water for locomotives and stationary boilers. Complete analysis.

Waste-water in ships and ferries. Determination of the content of chlorine and fat.

Paint-ingredients for ships and ferries. Determination of ferric oxide, quicksilver, arsenic and copper.

Among the testing-methods investigated by the machine-division the following may perhaps be considered to be of greater interest:

The test of coal which is more thoroughly described in number 34/1906 of »Ingeniøren«.

Determination of the hardness of materials through forcing stell-discs into the material and afterwards measuring the mark produced in the material. The apparatus used for these tests may eventually be shown and explained at the congress.

c. Account of the Tests of Materials made by the Artillery¹⁾.

For the testing of arms and other things used by the artillery and of the materials used to the producing of them a great number of tests are made yearly. These are partly made at the different workshops such as forging and hardening tests, partly as shooting tests in the commission for tests and at the control of small arms, the shooting-school, and the laboratory-workshops while all tensile, impact, and bending tests together with chemical analyses are made at the testing laboratory of the artillery.

In the time from 1/7 1907—30/6 1908 are at this laboratory made:

122 tensile tests of various materials such as steel, cast iron, copper, brass, wire-ropes, hemp-ropes and amiantine.

37 impact-tests with steel and cast iron.

20 bending tests of steelpipes.

139 chemical analyses of various kinds of steel, copper and copper-alloys, lead and lead-alloys especially hard lead, tin, zink, aluminium, and amiantine, silkcord, silk-thread, flannel, vaseline-oil, vaseline, ferronate and other fatty substances.

¹⁾ Informations of lieutenant *Ove K. Ovesen*, manager of the Testing Laboratory of the Artillery.

Beside these examinations there are made a great number (530) of analyses on the content of moisture in gun-powder while all proper analyses on gun-powder and other explosives are made at the powder-works of Frederiksværk.

Moreover it may be said that the Artillery besides shooting-tests already at a very early time used other tests of materials for the testing and the judgement of the materials used for the ordnance and the ammunition.

Thus, in the year 1771 there was made tensile tests at the arsenal of Copenhagen by means of the so-called great Nuremberg-weighing-machine which was placed there, to determine the strength of gun-metal, whose composition — in the beginning of the 19th century — was tested by analysing the metal of several various bronze guns.

In the year 1805 there was stimulated certain impact tests and drop tests before the acceptance of iron-axles for waggons, as well as they also used impact tests and drop tests in the beginning of 19th century at the receipt of grenades and shells.

Before the acceptance of guns they also used impact tests. Thus, complete impact tests were made at Stafsjö in Sweden at the receipt of 47 pieces of 84-Pds. Two test bars for each gun, one with a circular the other with a quadratic cross-section were placed with a certain distance between the supporting edges and plyed with a ram of a certain weight and with increasing height of fall, till the bars were broken.

During the casting of the guns belonging to the system of 1834 one or several test bars were cast at the same time as each gun. These bars were broken with a hammer and the hardness of the iron was determined according to the strength of the blow and the appearance of the surfaces of fracture. Then a few discs were turned of the test bars, and their specific gravity was determined. These tests were used, till in the years 1877—78 they besides began to test the quality of the iron by tensile tests, whereafter they proceeded to use these.

d. Account of the Testing of Materials at the Royal Navy-Yard¹⁾.

As a rule the Royal Navy-Yard had in earlier times particular rules for testing the more important materials it was furnished

¹⁾ Informations by Mr. *I. C. Tuxen*, director of the Royal Navy-Yard.

with, like iron, steel and other metals, wood, coal, canvas etc. and now and then testing of materials was employed to find the best methods to secure the most favourable quality of the materials for the use of the Royal Navy-Yard.

As the more important materials now are imported from foreign countries we have during the later years turned to follow the specifications for testing which are used in the navies of the more important countries and especially the specifications of the navy of the country which furnishes us with the materials. By this method a great advantage is obtained both with regard to economy and to reliable furnishing as the great foreign manufacturing more easily can procure materials answering to the requirements which are made by a great consumer like the navy of the country itself than procuring the materials as we — a comparatively small consumer — want them, according to special specifications.

In consequence of this manner of proceeding which on the whole has proved to be very favourable to the Royal Navy-Yard there are not during the later years made testing of materials which may be supposed to be of interest for the members of the congress.

e. Account of the Tests made by the States Technical Office for Testing of Paper¹⁾.

The States Technical Office is founded in 1888 and has since then tested the paper used by the government itself but made no tests for private people. The tests have included the determination of the paper's strength, resistance to creasing and folding, determination of ash and microscopical examinations, all according to the usual methods.

Further the office has tested ink and the like.

f. Various Other Informations.

Besides tests of materials have been made at several other places. Thus, with regard to investigations of wood, Mr. *E. Hornemann*, forest assistant, published in »*Tidsskrift for Skovbrug*« (Journal on forestry) V. XI, 1889, »Some investigations on the

¹⁾ Informations by Mr. *K. Prytz*, Professor of the Royal Polyt. Inst., and Mr. *Chr. Christensen*, manager.

technical properties of the wood of Danish common spruce», which he had carried out by means of a subvention from the government. After his decease his work was, after the proposal of Mr. *Oppermann* and Mr. *Prytz*, professors at the Royal Veterinary and Agricultural College, continued by Mr. *C. V. Meldahl*, graduate in forestry, who published «Some investigations of the strength of Danish and Foreign conifers» in »*Tidskrift for Skovvæsen*« Vol. V, 1893. By the investigations was found, that with regard to strength Danish common spruce was not much inferior to Swedish nor German and that mostly for the inner parts of the log only. Meldahl made also investigations about wood's resistance to wear and for this purpose he, as we presume, employed for the first time sand-blast in the service of the testing of materials (see B III, i).

Some years ago there was established an experimental department of forestry.

See also the last part of B III, k.

Further, the Telegraphic Department and various laboratories and factories have employed testing of materials. *V. Stein's* Laboratory has at an early date tested cement, and at the Royal Polytechnical Institute a series of tests on danish lime for building purpose was commenced about 20 years ago and were continued later on with tests of Portlandcement from this country. These experiments were executed by *N. P. Nielsen*, mech. engineer, and when these had finished in 1894 a States Laboratory for Testing of Cement¹⁾, directed by him, was established for some years at the last named institution, but this as well as *V. Stein's* laboratory for cement-testing were in 1896 swallowed up by the Danish States Testing Laboratory.

g. Informations about The Danish States Testing Laboratory and its Work.

The Danish States Testing Laboratory is established 1896 by the Danish Society of Civil Engineers especially by the energetic initiative of its president at that time Mr. *G. A. Hagemann*, now

¹⁾ On the experiments which here were executed for Mr. *Grut*, captain in the Royal Engineers, on the elasticity of concrete when subjected to tension see congress reports IX, 1. c.

Director of the Royal Polyt. Institute. The Society pledged itself to cover an eventual deficit, if the government would permit the institution to carry the name of the States Testing Laboratory and would pay a small annual subsidy. In this manner the States Testing Laboratory was carried on till 1st of April of the present year, when the government took the entire charge of the institution, as the minister of the interior the Hon. Mr. *Kl. Berntsen*, carried through the parliament a law thereof.

A special department of it: the laboratory for clay-testing which was established by means presented from *Skrikes* institution and which had a board of its own was at this opportunity incorporated in the States Testing Laboratory.

On page 19, fig. 5 on the right it may be seen how modestly the States Testing Laboratory began its work in 1896 in *Vestervoldgade 7*. Even now it resides very modestly in a hired flat in *Malmøgade 7*. The laboratory is technical adviser for the Danish customs. In some rooms adjoining it the Royal Polytechnical Institute has its place for training students in the testing of materials.

In the course of the years the States Testing Laboratory has been equipped with the following machines and apparatus:

A complete equipment for cement testing including a 32 Ts. hydraulic press from *Amsler-Laffon*, a *Ferets* bending apparatus etc.

A 50 Tons machine for tensile-, compression- and bending-tests from *Tinius Olsen* in Philadelphia.

A 120 Ts. *Brinck & Hübner* hydraulic press.

A machine for testing abrasion, System: *Dorry*¹⁾.

A lever-aparatus for compression-tests of cement- and clay-pipes.

Besides: An electric furnace (see later) and other furnaces for testing of clay, a *Berthelot-Mahler* bomb calorimeter and various other small apparatus.

Although the laboratory is thus only modestly equipped with machines and apparatus when compared with the great institutions of foreign countries it has however in the course of the years been able to make tests to an amount of ca. 200,000 Danish crowns

¹⁾ »Baumaterialienkunde« 1902, p. 313.

and the materials tested at the laboratory have thus been of rather great value.

The increase in the work of the laboratory appears from page 20, fig. 6, where the ordinates indicate the annual income in thousands of danish crowns for tests made during the 12 years passed. The printed price-list include 285 various tests.

The laboratory has every year published an annual report in »Ingeniøren«; but besides it has now and then in the same journal published its researches especially on series of tests of scientific-technical nature. These informations treated the following subjects:

»Ingeniøren«

- I. The 50,000 kg automatic and autographic testing machine from *Tinius Olsen & Co.*, Philadelphia.... 1898, Nr. 11, p. 77
- II. Tests of India rubber packings 1899, » 15, » 119
- III. Linoleum 1900, » 44, » 339
- IV. Tests of clinkers to wear 1901, » 14, » 73
- V. Tests regarding the restoration of the exchange of Copenhagen 1902, » 8, » 57
- VI. Researches regarding the restoration of the facade of Thorvaldsens museum 1903, » 2, » 9
- VII. Pyrometric tests of some Danish sorts of clay 1903, » 12, » 89
- VIII. Report of tests of steam-pipes and gas- and water-pipes made for the pipe-committee of the Danish Society of Civil Engineers 1903, » 42, » 293
- IX. Investigations as to the practical use of »Moler« in the Industry 1904, » 24A, » 177
- X. Experiments on painting on fresh, surface-dry or moist plastering of cement-mortar 1905, » 28, » 183
- XI. Preliminary report of a series of tests regarding means of preserving wood 1905, » 45, » 295
- XII. Researches on linseed oil and rust-preventing means 1906, » 1, » 1
- XIII. Tests of cement- and clay-pipes 1907, » 29, » 211

- XIV. Tests of cement-bricks 1907, » 46, » 341
- XV. Tests of resistance to frost of sand-
lime-bricks 1908, » 37, » 290
- XVI. Results of the testing of various ma-
terials: cast iron, chains, wire-ropes,
hemp-ropes, diatomaceous deposit .. 1909, » 33, » 307

About smaller series of experiments there are informations in the annual reports. A few of the series treated new testing-methods and apparatus. Further the above mentioned special department of the States Testing Laboratory, the testing laboratory for clay, has published a series of 13 reports of tests in the journal »Nordisk Tidsskrift for Lervare- og Stenindustri« (now. »Lerindustrien«).

In the following is given an abstract of some of the publications of the States Testing Laboratory.

The Danish States Testing Laboratory in Copenhagen,
the 1st of August 1909.

H. I. HANNOVER.

B. Summary of the Publications of the Danish States Testing Laboratory¹⁾.

I. Investigations on Metals.

As to investigations on metals, the Laboratory has only to a slight extent been able to set up experimental series as the expenses in fashioning test pieces would be too great for the small means which were at our disposal. Only in one domain a larger experimental series has been set up, namely with respect to testing of pipes of malleable iron (Report VIII), because The Society of Danish Engineers wanted a greater series of tests in order to establish appropriate testing methods for the drawing up of specifications for delivery of such pipes.

To the 4th International Congress in Brussels in 1906 the Director of the Laboratory, Professor *Hannover*, submitted the results of this experimental series and the Danish specifications that had been agreed upon, to which we refer here²⁾.

It may, perhaps, be of interest to see how pipes tested later — i. e. from the conclusion of the experimental series until Jan. 1. 1909 — have gone through the tests prescribed:

As to steam pipes tensile tests were made with 8 deliveries, the tests being made with altogether 41 pipes. Among these 41 pipes the test proved unsatisfactory for 5 pipes. In one of these pipes the strength was too slight, namely only 31,9 kg pr. sq. mm instead of at least 33 kg pr. sq. mm, in 3 the elongation was too small namely 9,9, 9,0 and 7,8 per cent instead of at least 12 per

¹⁾ The summary has here and there been supplemented with details not formerly published.

²⁾ The German minutes of proceedings, p. 173.

cent, and in 1 pipe both strength and elongation were too small, namely respectively 31,5 and 11,7.

For steam pipes bending tests were made with the same 8 deliveries, but only with altogether 34 pipes. Of these only 1 did not stand the test, but broke in two athwart, namely the pipe where the elongation of the material was but 9 per cent.

As to gas- and conduit-pipes tensile tests were made with 5 deliveries, the test being made with altogether 33 pipes. Among these 33 pipes the test proved unsatisfactory for 6 pipes.

In 3 of these pipes the strength was too slight, namely respectively 30,0, 31,3 and 31,2 to 32,0 instead of at least 33 kg pr. sq. mm, in 3 others the elongation was too small namely 10,3, 11,8 and 6,8 to 7,9 instead of at least 12 per cent. By the pipe with a tensile strength of 30 kg pr. sq. mm. the elongation could not be measured, the fracture falling outside the gauge length.

For gas- and conduit-pipes bending tests were made with the same 5 deliveries, but only with 31 pipes. Of these 2 did not go through the test, the one broke in two athwart, namely that one whose tensile strength was 30 kg pr. sq. mm, by the other the weld opened in no small degree.

At the Congress in Copenhagen Mr. *Karsten*, chief-engineer in the municipality of Copenhagen, will read a paper upon testing of pipes of malleable iron and render a detailed account of the results of the tests dealt with here.

On testing wire-ropes, the wires of the rope are usually uncoiled and an alloy cast round. As it appears from p.24, fig.7, the socket where the casting takes place is on the middle of the under side turned so as to form a spherical face resting during the tensile test against a corresponding depression, so that a central clasping is obtained by the thus produced spherical movement.

For impact test on cycle-front-forks the Laboratory has constructed the apparatus shown in fig. 8 at p. 25.

The front-forks steering column is fixed so that the fork-sheaths G project horizontally and are loaded at the extreme end, as it appears from the figure, by the attaching of a weight P of 93 kg. whereupon the current to an electro-magnet E is interrupted, so that the anchor A hanging below and weighing 2,16 kg, falls down on P through a height of about 18 centimetres.

By means of the test it is examined whether the forks are damaged, the Laboratory having decided upon a certain deforma-

tion of the fork as the greatest allowable and arranged a special measuring instrument for the purpose of quickly determining whether this is surpassed or not. Among the 370 forks tested up to the 1st of Juli 1909, altogether 8 forks did not stand this impact-bending-test.

After having been subjected to this test the front-forks were subjected to a tensile test in order to ascertain whether during the impact test a hidden fissure had appeared or a soldering been broken.

In the tensile test apparatus the pulling force of 500 kg is exercised in turning by means of a very long lever an axle on which a chain is hereby wound up. This latter then pulls a nut on the steering column of the front-fork some iron-bars stuck down into the concrete-floor resisting either against the crown or against a transverse bar through the axle holes at the ends of the sheaths, namely if the holes have a closed circumference. A dynamometer is inserted between chain and the nut on the steering-column. By means of a special coupling piece the dynamometer can easily be coupled to the nut and separated after the test.

All forks tested have gone through the pulling test.

Except a single one only new front-forks were tested, and in none of these the test has occasioned any fracture. It is therefore not quite possible to judge of the value of the test, as the test would presumably be best suited for ascertaining a beginning fracture in used front forks.

There are, for the rest, now reinforces to be put on within the steering-column and whilst the test may be worthy of recommendation to vendors of cycles on purchasing lots of front-forks the purchase of a reinforce will presumably be preferable to private persons in spite of the somewhat greater expense.

The Danish standard specifications for cast-iron differing from the German, it being claimed in Germany that a bar with a distance of 1 m between the supports and a height and breadth of 30 mm shall be able to support a weight in the middle of 450 kg which according to the usual bending formula corresponds with a modulus of rupture of 25 kg pr. sq. mm., whilst it is claimed in Denmark that a bar with the same distance between the supports, but of a height and breadth of 25 mm shall be able to support a weight in the middle of 300 kg which corresponds with 28,8 kg pr. sq. mm, it may perhaps be of some interest to see

how cast-iron bars have gone through the bending tests at the Laboratory, 26 pieces having in the course of the years been tested according to the German standards specifications and 29 according to the Danish (Report XVI of the Laboratory).

The named 26 experiments proved to give an average modulus of rupture of 26,7 kg pr. sq. mm, 3 of the results being below 25 kg pr. sq. mm, whilst the average number of the last 29 results was 28,8 kg pr. sq. mm of which 16 results were below 28,8 kg pr. sq. mm.

As to more special tests, it may be named that the Laboratory has made *Brinell* tests of hardness, *Heyn* impact-tests on notched bars and has through a longer series of years carried on microscopical examinations of metals.

II. Examinations of Cement.

In the course of time the Laboratory has made a great many current examinations, for instance for The Hydraulic Engineering Department who uses large quantities of cement, especially in working on the protection of the west coast of Jutland, for the municipality of Copenhagen for the new sewerage

Table I. Results of Examinations of Cement in 1908.

	Time of setting	Erdmen- gers high- pressure- steam- test		3 days		7 days		28 days		3 months	
		tensile	com- press.	tensile	com- press.	tensile	com- press.	tensile	com- press.	tensile	com- press.
Values obtained . .	7½ hours	26,7	339	13,6	104	19,7	194	25,7	313	31,1	383
Number of Cements	111	75	73	51	48	64	65	81	79	23	23
The five highest results were between		37,3 and 43,3	500 and 551	17,7 and 23,5	133 and 191	25,9 and 28,1	296 and 327	32,8 and 35,7	496 and 551	33,7 and 41,0	471 and 591
The five lowest results were between		0-0	0-0	4,1 and 9,2	18 and 70	6,9 and 10,8	46 and 104	13,2 and 17,8	117 and 168	19,7 and 28,3	185 and 283

of Copenhagen etc. — in later years also some cements for constructions in reinforced concrete. A general view of the properties of the cement employed in Denmark will be obtained from the collection given in Table I and II of the results of the examinations of cement in 1908. In 1908 167 examinations of this kind were accomplished. All these except one went through the standard test for constancy of volume.

Table I gives the means of all the results (except the setting time for quick-setting cements) of tests of setting together with tensile and compression-tests after 3, 7, 28 days and 3 months from the examinations of cement made in 1908. The values of

Table II. Results of Complete Examinations of Cement made in 1908.

Time of setting	Erdmengers high pressure-steam-test		3 days		7 days		28 days		3 months	
	tensile	compress.	tensile	com-press.	tensile	com-press.	tensile	com-press.	tensile	com-press.
6 $\frac{1}{2}$ hours	27,5	378	15,0	101	17,9	154	19,8	230	30,2	315
8 —	36,5	430	11,9	92	18,0	183	22,0	286	33,0	364
6 $\frac{3}{4}$ —	31,7	445	13,9	104	19,5	190	27,8	339	33,7	414
7 $\frac{1}{2}$ —	33,8	430	14,5	114	23,2	244	35,7	486	35,9	591
7 —	The test-pieces were disintegrated		10,6	84	10,8	100	17,5	168	29,6	252
6 —	do.	do.	11,7	88	10,7	104	17,8	162		
5 $\frac{1}{2}$ —	35,7	360	16,0	112	23,1	204	25,1	327		
7 $\frac{1}{4}$ —	36,2	459	18,2	114	21,4	187	27,0	296	31,1	369
7 $\frac{3}{4}$ —	33,2	427	16,0	114	20,1	186	28,3	294	29,9	382
6 $\frac{1}{4}$ —	36,2	470	16,4	131	20,7	209	27,0	318	31,0	398
7 $\frac{1}{2}$ —	27,9	379	14,2	126	16,6	127	23,8	226	28,0	324
3 minutes	17,9	165	9,6	60	10,0	70	13,2	117	19,7	185
6 $\frac{3}{4}$ hours	35,4	500	16,1	127	22,4	212	27,7	352	33,4	466
8 —	35,6	500	15,6	115	23,1	266	31,8	431	32,0	497
6 —	10,3	123	11,3	88	16,6	171	25,6	319		
6 $\frac{1}{2}$ —	35,6	484	17,7	148	21,5	277	28,8	377	31,5	448
8 $\frac{1}{2}$ —	The test-pieces were disintegrated		13,6	114	17,4	162	21,0	210		
8 —	27,3	349	13,3	93	15,1	131	23,1	206	28,1	269
6 $\frac{3}{4}$ —	35,4	480	16,9	133	21,0	206	26,4	333	36,1	471
7 $\frac{1}{4}$ —	23,9	198	16,2	106	18,7	206	24,9	318	30,5	401
7 $\frac{1}{2}$ —	23,6	314	4,2	41	6,9	68	17,8	158	25,5	234
11 —	27,1	362	16,7	116	19,1	157	22,9	221	29,2	302
7 $\frac{3}{4}$ —	40,1	478	17,7	145	28,1	284	33,8	497	41,0	569
7 $\frac{3}{4}$ —	43,3	551	23,5	191	28,0	286	34,0	505	36,4	532
7 —	37,3	473	16,1	111	21,2	202	26,1	318	32,7	413
6 $\frac{1}{4}$ —	The test-pieces were disintegrated		12,3	96	13,8	135	16,8	209	28,3	283
about 45 min.	27,1	303	9,6	52	13,6	115	20,5	209	28,7	332

strength are given in kg pr. sq. cm. In the next column is given the number of cements for which the results are means, and in the following columns the 5 highest and 5 lowest results obtained in the course of the year for the various tensile and compression-tests.

In Table II are stated results of all the examinations of cement of 1908, by which the strength of the same cement has been determined both after 3, 7 and 28 days and (except in 4 cases) after 3 months; high-pressure-steam tests have also been made.

By the above mentioned *Erdmenger* high-pressure-steam test test-pieces for tensile and compression-tests are moulded in the usual way of the cement, and after being left 24 hours in moist air, they are laid in water in further 2 days and then boiled in a small boiler at a pressure of 10 atmospheres for 6 hours and tested for tension and compression. To institute a comparison 3 days tensile and compression-tests are also, as a rule, made in the usual way. The tests invented by Dr. *Erdmenger* in Hannover is an accelerated test for constancy of volume, which as far as our knowledge goes is used no more elsewhere, but to a rather great extent in Denmark. It is thus prescribed in the specifications of delivery of The Hydraulic Engineering Department. The Laboratory having also made a great many accelerated tests by the method of *Le Chatelier*, the results obtained by the two methods will be given here for those cements, for which both tests have been made until the 1. of January 1907, — see Table III.

As it seems to appear from the comparison of the results of the *Erdmenger* test and the *le Chatelier* test, that these results differ very much, a graphical sketch is given of them at page 30 in fig. 9 in order to obtain a better view. The results of the former tests are given in making a notch in the sloping straight line for each test, namely in that point of the line whose ordinate counted by the statements on the left side of the figure represents the compression strength according to the test. For each cement a cross in the same ordinate points out the result of *Le Chatelier's* test, the increase of distance between the needles being marked out from above downwards according to the statement on the right side of the figure. 4 results, where the distance between the needles was less than 1 mm or exceeded 11 mm, are left out. At discretion a curve has then been

Table III. Juxtaposition of all Results obtained until the 1st of January 1907 for Cements with which have been made both 3 Days Test, the Erdmenger High-Pressure-Steam Test and the Le Chatelier test.

3 days		Erdmen- gers high- pressure- steam- test		Le Chatelier test	3 days		Erdmen- gers high- pressure- steam- test		Le Chatelier test	3 days		Erdmen- gers high- pressure- steam- test		Le Chatelier test
ten- sile	com- press.	ten- sile	com- press.	Le	ten- sile	com- press.	ten- sile	com- press.	Le	ten- sile	com- press.	ten- sile	com- press.	Le
11,6	65	9,1	32	9,8	—	77	—	170	1,8	7,5	42	25,2	279	3,0
10,3	73	—	c.37	5,5	—	—	24,4	172	3,0	9,2	58	19,3	280	2,3
15,1	75	11,0	52	9,3	9,0	46	24,4	177	8,5	14,2	74	29,6	281	0,8
12,1	71	10,8	58	10,3	10,6	80	21,5	179	1,8	9,7	68	27,0	286	1,0
11,9	66	8,3	59	10,8	10,6	43	20,4	181	2,5	12,9	105	25,6	286	4,5
17,2	125	6,3	67	10,0	12,9	74	20,4	188	2,5	16,0	106	27,4	292	0,8
6,2	39	9,1	67	14,0	12,8	74	26,2	189	2,5	12,5	92	29,3	294	0,8
13,2	119	6,6	76	4,0	12,2	61	24,5	193	1,3	11,5	63	25,5	297	2,5
7,6	52	5,9	80	19,0	12,2	118	15,6	195	5,5	12,3	77	26,7	298	2,3
11,4	113	6,0	81	4,8	8,0	49	21,2	199	2,0	13,5	126	33,7	309	2,0
11,2	65	13,8	86	6,5	13,5	73	26,8	202	2,8	13,2	107	29,1	316	2,5
13,4	79	16,9	88	5,5	12,7	51	24,4	203	1,5	13,4	112	28,1	330	2,0
—	71	—	89	22,2	8,1	35	23,9	203	1,0	13,8	101	28,7	331	1,8
14,6	80	16,1	92	3,8	3,2	41	24,9	204	1,5	14,0	79	29,7	371	6,5
8,1	62	11,6	96	9,0	12,2	71	24,3	218	6,0	12,1	66	35,0	377	1,3
9,5	58	19,0	97	3,0	9,3	44	30,3	219	2,8	14,9	123	30,2	391	2,0
13,9	84	12,3	100	5,8	11,5	63	23,8	225	2,5	15,1	110	40,7	391	0,5
8,9	76	28,4	100	1,8	9,4	73	28,8	227	1,8	12,2	114	29,2	399	3,3
11,8	77	32,6	103	3,0	11,6	41	23,9	227	0,8	12,7	94	30,5	400	2,3
10,1	97	8,5	110	12,8	10,4	65	28,0	229	2,3	12,8	94	36,8	404	2,0
13,9	140	13,7	127	7,8	10,0	66	26,7	236	2,0	15,3	117	30,6	420	1,3
—	80	—	130	2,5	12,6	71	23,2	241	1,0	11,0	75	30,5	424	1,5
14,6	85	28,3	140	4,0	10,4	63	21,7	243	1,8	12,8	98	31,0	425	2,0
11,5	62	24,2	143	1,5	8,2	46	25,5	244	1,3	9,6	58	33,0	427	1,3
13,6	74	16,5	153	6,3	10,5	84	25,7	245	2,0	14,0	121	32,3	433	1,5
17,0	96	27,6	154	4,3	8,0	59	23,7	248	1,8	10,3	114	26,2	434	1,8
11,6	82	17,0	154	5,0	16,8	84	26,6	250	2,3	15,9	98	31,4	438	3,5
6,6	23	19,8	156	1,3	11,8	82	27,0	257	2,5	12,1	95	29,2	441	1,3
—	71	—	160	3,3	12,4	78	25,0	262	2,3	17,7	133	31,9	460	1,3
15,7	115	13,8	161	3,0	11,8	84	22,9	265	1,3	14,2	101	38,0	483	1,8
11,3	110	14,2	162	6,8	8,5	62	24,0	266	1,3	12,0	110	41,1	502	1,8
11,9	80	22,1	165	8,5	13,5	66	25,3	277	2,0					

laid out indicating the position of the said crosses. The uppermost part of this curve is seen to be horizontal from which it appears that the *Le Chatelier* test gives, as a rule, divergences of but about 3 mm between the points of the needles as long as the Erdmenger tests prove a crushing strength of more than about 200 kg. But on the strength according to the latter test sinking below this, the divergences by the *Le Chatelier* test

increase very much in size, which is proved by the curve passing into an abruptly downhill branch.

The Laboratory has made some experiments with Feret cement prisms to institute a comparison with the common standard tests, especially for determining the influence on the strength of different additions of water and different stamping of the prisms. A report of some of these experiments, has been sent to Prof. *Schüle* in Zurich, the chairman of the Committee 42.

The Sub-Director in charge of the Laboratory, Mr. *Mayntz Petersen*, has already before the Congress of Brussels, made some experiments for the committee 30 for determining the quantity of fine particles in cement, see Professor *Gary's* report to the Brussels Congress; the experiments, which have been executed for the Association of Scandinavian Manufacturers of Portland cement, have later been completed, and report has been given to Prof. *Gary* for the use of his discourse at the Congress in Copenhagen.

Assisted by the Laboratory the same association has as early as 1896 commenced a series of experiments on the resistance of cement mortar to the influence of the sea water, for which 4000 cubes were produced by the Laboratory and immersed in different places of the Scandinavian seas. On the part of the said association Mr. *A. Poulsen*, chief-engineer at the Hydraulic Engineering Department in Lemvig, will give an account at the Congress in Copenhagen of the results obtained up to this time.

The Congress of Brussels had resolved that the test for determining the normal consistency should be made in a mould inside conical with 400 g cement in a way the details of which were given more particularly. It has, however, appeared from the experiments of the Laboratory, that this quantity of cement is rather small, which has been further strengthened by experiments made by Prof. *Mesnager*, wherefore the Laboratory intends through Sub-Director *Mayntz Petersen* to place before the Congress in Copenhagen the question of an amendment in the rules agreed upon in Brussels as to this point.

At the Laboratory various other researches have been made on cement, for instance, on the faculty of cement mortar in protecting iron structures from fire. Some other experiments made for Mr. *Grut*, Captain of the Royal Engineers, on the strength of

cement, when exposed to higher temperatures have been published by Mr. *Grut* in »Den Tekn. Forenings Tidsskrift« (Review of the Technical Society) 1903—4, Vol. 27, p. 206 — see the report to the Congress IX 1 c.

As to some researches on cement plaster, see III f.

III. Other Researches.

a. Testing of Natural Stones.

The Laboratory has, of course, made the common examinations of the crushing strength of natural stones, their power of absorbing water, resistance to frost and resistance to wear etc.

The resistance to wear is determined by means of the Dorry wear testing machine, named p. 21, where the loss of weight as well as of height is determined. The following Table IV gives the results obtained by the Laboratory until the 1st of January 1909 of tests of resistance to wear of both natural and artificial stones.

As an instance of a greater series of examinations made of natural stones may be quoted researches undertaken 8 years ago in consequence of the restoration of the Exchange in Copenhagen.

A restoration made 20 years before where the stone-work had cost about 100,000 Kr. proved namely to have been of transitory use, large pieces falling off the images on the building cut out in Gothland sandstones. For one thing the researches of the Laboratory tended to make out how fluating would act upon the Gothland sandstone as well as regards its resistance to frost as to wear and to compare new Gothland sandstone and old ditto from the Exchange in both unfluated and fluated state with sandstones from Obernkirchen in Hessen-Cassel (in Denmark called Bremer-sandstone) as to their quality of being weather-proof, namely by the tests pointed out by Prof. *Seipp*¹⁾. A summary of the report V of the Laboratory on this series of examinations was embodied in »Baumaterialienkunde« 1902, p. 218. From this may be quoted that fluating protected to some extent Gothland sandstone from frost and wear, but that the fluated and unfluated Gothland sandstones did not differ much, when going

¹⁾ Prof. *Seipp*: Die Wetterbeständigkeit der natürlichen Bausteine und die Wetterbeständigkeitsproben, Jena 1900, p. 176.

through *Seipp's* test of resistance to the weather, whereas the Bremer-sandstones held their own much better than both of

Table IV. Tests of Resistance to Wear with Clinkers, Concrete-Flags and Other Stone Materials.

Loss of height in mm	Earthen-ware		Concrete-flags and Cement-flags	Granite and Gneiss	Marble	Lime-stone	Asphalt	Flint	
	Clinkers	Flags							
up to 1 mm . . .	1	2	12	16				12	
from 1,1—2 — . . .	30	4	43	3			2	2	
- 2,1—3 — . . .	19	6	19				12		
- 3,1—4 — . . .	6	4	7		1	2	7		
- 4,1—5 — . . .	13	6	4		1		4		
- 5,1—6 — . . .	7	5	2		1		1		
- 6,1—10 — . . .	12	7							
- 10,1—16 — . . .	5	3			1				
- 16,1—20 — . . .		3							
Number of Sorts . . .	93	40	87	19	4	2	26	14	altogether 285

Loss of weight
in g pr. sq. cm
of area subjected to
abrasion

from 0,1 — 0,2 g. . . .	4	3	7	9				16	
- 0,21—0,3 —	6	2	20	10			1		
- 0,31—0,4 —	14	1	15						
- 0,41—0,5 —	16		19				4		
- 0,51—1 —	25	13	25		1	2	19		
- 1,1 — 2 —	22	2	1		2		2		
- 2,1 — 3 —	6	9			1				
- 3,1 — 4 —		3							
- 4,1 — 5 —		4							
- 5,1 — 6 —		1							
- 6,1 — 7 —		1							
- 7,1 — 8 —		1							
Number of Sorts . . .	93	40	87	19	4	2	26	16	altogether 287

The loss of height has not been entered for two sorts of flint.

them. On the building being restored later on fluating was employed on a large scale in those stones that could be restored, but where exchange was necessary, Bremer-sandstones were employed. According to researches made the Laboratory was able

to recommend for cleaning the stones before the fluating to perform this as thoroughly as possible with iron wire-brushes, for on fluating parts not well cleaned and then going on cleaning, there was danger that the cleaning with the wire-brushes should deposit so much iron on the stones, now hard, that the fluating afterwards caused rusty spots.

b. Testing of Bricks and Exminations of their Raw Materials.

For the tests of these bricks, which since the starting of the above named Clay-Laboratory have been made here, the usual methods have been employed in examining their resistance to crushing, power of absorbing water, resistance to frost, contents of dissoluble salts, contents of injurious grains, adhesion to mortar etc.; further special examination have been made of the resistance to wear of clinkers¹⁾, of the permeability of tiles, of the resistance to the weather of glazed goods, of fire bricks as to their refractoriness, their constancy of volume during their burning, their resistance to change of temperature etc.

As special researches on bricks may be quoted the following, some of which are treated upon in some of the 13 reports of experiments published by the Clay-Laboratory of the Danish States Testing Laboratory, namely

1. Comparative experiments of adhesion between »Moler« bricks and common bricks.
2. Drying experiments with »Moler« bricks, common yellow bricks and clinkers.
4. Comparative tests on strength of bricks burnt in brick-manufactories and samples burnt at the laboratory.
5. Glazing on lime-charged goods.
8. Saturating and Colouring of the interior of yellow tiles.
9. Saturating of red tiles with milk that has passed through a cream separator.
10. Saturating of red tiles with water-glass.
11. Comparative researches on cement-bricks and common bricks.

¹⁾ On this Report IV had already been published before the founding of the Clay-Laboratory.

The Clay-Laboratory has, of course, on a large scale dealt in researches on the applicability of clay and other raw-materials for the producing of bricks.

The first greater research of this kind treated on: Pyrometrical Examinations of some Danish Sorts of Clay (Report VII of the Laboratory).

To make these researches with sufficient accuracy it was necessary to procure a furnace by means of which not only the sufficient temperature could be reached but also be regulated and especially kept constant over a longer period. On this proving very difficult with the existing gas-furnaces it was resolved to construct an electric furnace.

For some former experiments made for the Danish States Testing Laboratory Mr. *Absalon Larsen*, then M. A., now Professor of the Royal Polyt. Institute, had for another purpose employed as an electric furnace an externally screwcut chamotte-cylinder with a winding of nickel wire inlaid in the screw-worms, which was run through by electricity. The Laboratory being still in the possession of this furnace, it was decided to employ it for the chamber itself of the new electric furnace.

During the said experiments, however, no higher temperatures than about 1000° Centigrade had been attained, wherefore it was resolved to try first how high temperatures could be reached on the cylinder being well isolated.

The cylinder was then inwrapped with a double nickel wire, the diameter of each wire being 1 mm. The inwrapped cylinder was put down into a cesspool of salt glazed clay in the bottom of which was a layer of sand, then asbestos flakes and finally a layer of kaoline. The cylinder was then imbedded in a layer of kaoline separated by an asbestos cylinder from an outer layer of asbestos flakes. The temperature was observed by means of *Le Chatelier's* pyrometer the junction of which was placed in the middle of the chamotte cylinder. At the top the cylinder was shut with a chamotte stopper in the middle of which was a hole through which the pyrometer could come down.

At a temperature of about 1400° Centigrade reached after about 2 hours the wire was burnt over, but it appeared clearly from the table drawn up of the rising of the temperature, that if the winding had been platinum, a considerably higher tem-

perature could have been reached, the final interval displaying a rising of 3—4 degrees in 1 minute.

It was now resolved to produce the furnace, a longitudinal section of which is seen at p. 36 in fig. 10¹⁾, with a platinum winding of a thickness of 0,8 mm. The ends of the winding, for possible tensions made double from the chamotte cylinder B, were led out through the cylindric surface of the cesspool, and fastened here to two connection binders I—K. The pyrometer F was also led through the cylindric surface in such a way, that the junction was placed in the very centre of the axis of the chamotte cylinder. The furnace in its final form coming to lie horizontally an asbestos plate G was placed on the front side to keep hold of the Kaoline and the Asbestos flakes. C is a bottom plate, D and E the closure of the furnace.

By the first experiment with the new winding, it was decided to try to reach 1500° Centigrade and to observe how soon this point could be reached.

It was proved that this temperature could be attained in the course of about 1 hour and a half.

There was now laid a special conduction to the furnace and set up a switch-board with a single-poled interruptor, an Ampèremeter, an automatic interruptor, interrupting at 17 Ampère, 2 wire-rheostates of respectively 2 and 10 Ohm and the necessary connection binders and securities. On the regulation of the current being not so complete as desirable and the current being at first rather strong, a water resistance, consisting of a glass-vessel with 2 accumulator-plates, was added somewhat later.

P. 37, fig. 11 shows the furnace with switch-board etc.: L is securities, M interruptor, N ampèremeter, O automatic interruptor, P wire-rheostates, Q water resistance and R a millivoltmeter for the pyrometer.

On the whole this furnace has not fallen short of the expectations formed of it. It is exceedingly easily regulated. For hours the temperature can be kept constant perhaps oscillating 5° from the point of equilibrium.

As above stated the furnace can exceedingly well be used at temperatures up to 1500° Centigrade. The Laboratory does not,

¹⁾ At fig. 10 Kaolin means Kaoline and Asbest Asbestos.

however, employ it at higher temperatures, than 1400° Centigrades which has proved fortunate for the durability of the platinum winding. At some experiments where the temperature remained continually at about 1500° for some hours a quite new platinum-winding was burnt over after a very slight number of burnings. If, however, employed only at temperatures below 1400° Centigrade, a platinum winding can be reckoned upon lasting 700—800 burning hours.

With the above named furnace have been made a greater series of experiments on the producing of clinker-compounds (Report VII of the Laboratory).

Among the series of experiments of the Laboratory concerning researches of raw materials for the producing of bricks are to be noticed its researches on the applicability of »Moler« for building and industrial purposes (Report IX of the Laboratory). »Moler« is a local denomination for the eocene, argillaceous, foliated diatomaceous deposit occurring in several places in Jutland and especially in the northern part of Mors, on Fur and elsewhere on the coasts of the Limfjord, thus a Silstrup and in Ertbølle Hoved. It has several times been tried to utilise »Moler« but without any result.

The experiments of the Danish States Testing Laboratory were occasioned by the present director of the Royal Polyt. Institute, Mr. G. A. Hagemann, proposing to try the producing of sand-lime bricks by mixing lime, moler and sand. It became apparent, however, that the moler was not adapted to this.

The Clay-Laboratory of the Danish States Testing Laboratory now commenced to try the producing of bricks by mixing up clay and moler in different proportions. Moler was mingled with 25, 50 and 75 per cent of marl and with 25 and 50 per cent of red clay; it was also tried to burn bricks from moler alone. It appeared from the burning that, contrary to our expectations, the moler alone gave a fine red brick, very firm and light; such a brick could have a nail knocked through without cracking.

After this result all later experiments were made with un-mixed moler.

It having been displayed that very light bricks could be produced from the moler (specific gravity about 1) and nevertheless of the same strength as common bricks, the committee of the Clay-Laboratory, as above named, indebted for its founding to

»Skrikes Institution«, applied to the latter asking the Institution to grant 1000 Kr. to continued experiments and for obtaining the right of spading of a stratum of moler with well adapted moler and good shipping conditions. The design was both to prevent the manufacturing from being commenced with less adapted moler and possibly bringing a bad name upon moler-bricks and to prevent eventual advantage from a remunerative manufacturing based upon the researches of the Laboratory from devolving unjustly on speculators or the share-holders in question.

On this occasion the chief-engineer of the Clay-Laboratory, Mr. *Fischer-Möller*, traversed the moler territory several times both in the company of Captain *Loof*, Hobro, and together with Dr. *V. Madsen*, State-geologist. On these travels they succeeded in finding an exceedingly well adapted stratum of moler at Ejerslev pr. Mors.

P. 40, fig. 12 shows a part of Ejerslev. In the place in question the cliff is 16—20 m high. To the right on the picture are distinctly seen strong throws and corrugations of the strata. The dark stripes are derived from strata of black volcanic ashes always following the moler. Where these strata of ashes occur in great quantity and density, they render the moler quite inapplicable for producing of light bricks.

As it was to be supposed from the experiments made on a small scale by the Danish States Testing Laboratory, that in utilising the strata of moler at Ejerslev a new Danish industry could be started, the next step must be to try a manufacturing in a brickfield, and Captain *Loof* kindly undertook the manufacturing in the brickfield of Vindø at Hobro, which is in his possession. The bricks whose moulding, drying and burning had caused several practical difficulties were now examined at the Testing Laboratory and, according to the burning degree and treatment, displayed a resistance to crushing of from 86 to 230 kg pr. sq. cm. The specific gravity was between 0,87 and 1,13, the latter figure for the hardest burnt bricks. Their power of absorbing water was in all cases considerable and could attain 50 per cent.

The most remarkable thing was, without doubt, the great strength of the moler bricks in proportion to their lightness and other light bricks in the market. Rhenish »Schwemmsteine«.

for instance, display a resistance to crushing of only 18—29 kg pr. sq. cm.

Moler bricks can be employed for partitions masoned directly on the floors without any other support than the latter and for floor-constructions and for vaults of every form. When used for vaults between iron-beams, the latter can be made less strong than on employing common bricks. As the bricks can be rendered nail-proof they can likewise as »Schwemmsteine« be employed for the fastening of the frames of doors. In the brick-field of Vindø were produced special bricks for the masoning of chimney corners in a line with partitions of boards. On account of the lighthness of the moler bricks, it is possible to employ bricks of the double height without their becoming heavier than common bricks. Thus the number of joints is decreased, less lime is employed, and piling, loading and unloading becomes easier. That moler bricks of the usual size are very comfortably managed by masons and labourers, and that twice the number can be loaded on railway-cars and lighters goes without saying.

Apart from being adapted to bricks of partitions moler bricks can be employed in the masoning of boilers, but not instead of fire-proof bricks, nor as outer bricks owing to their prominent water absorbing properties. (Nor are they, for the same reason, suitable as nether bricks in buildings). But their being bad conductors of heat renders them well fit for being placed elsewhere in the boiler-masonry. The slight thermal conductivity has been substantiated by various experiments, both at the Testing Laboratory and in the Eastern Gas-Works, where the manager Mr. *Irminger* placed some bricks as cover of the retort-bench above a retort comparing them with two different sorts of fire-proof bricks and common bricks. In the new poor-house »Sundholm« in Copenhagen, the chief-engineer in the municipality has had quite uniform boilers masoned both with and without moler bricks, so that it can be established by means of experiments also there, whether moler bricks are well adapted to the isolating of heat. Another competent authority has, for the rest, written a warm recommendation for moler bricks having proved excellent for boiler-masonry¹⁾.

The slight thermal conductivity in the moler brick is, of

¹⁾ Annual Report of the Laboratory for 1907, p. 6.

course, due to the many small air-holes occurring in and between the skeletons of the silicious algæ. For this reason the moler bricks will be well adapted as backing-bricks in outer walls, where the house is wanted to be sheltered. In hollow outer walls they will presumably be excellently adapted for the internal part of the wall. On account of the same property they will be suitable as vault bricks and for the covering of columns and beams in iron-constructions. It is also specially recommended to employ them in the walls of ice-houses, cooling-rooms and dairy premises and in cheese-rooms. These bricks can also be employed as filtering-stones and whetstones.

On a single very important point the moler bricks were, however, in want of research. It was not known, how the bricks would be able to resist the strong heat of a fire, and regarding their value as building material it was, of course, of great importance to become clear of this point. One was aware of the not slight shrinkage of the bricks during their own burning.

On this was thrown light by some experiments made by the Laboratory in 1907 for Frederiksholm's Brickworks Co. Ltd. given below.

»Result of fire test with one bricks wall built of moler bricks made according to the requisition of The Frederiksholms Brick- and Limeworks, Co. Ltd.«

An examination was wanted as to a one bricks wall being able to resist the effect of a fire without the bearing strength of the wall being diminished because the individual bricks were vitrified or melted.

In the territory of the Eastern Gas-Works an experimental house was built the construction of which appears from the present photographs. The experimental house had a height of 157 cm and was run up of one brick's wall. The middle transverse wall was built of moler bricks, namely 6" broad partition-bricks, sent in by Frederiksholm's Brick- and Limeworks. These bricks were laid with the breadth at right angles to the thickness of the wall and in bond with the outer walls consisting of yellow clinkers. Above the experimental house was covered with fire-proof bricks placed so close, that there was just sufficient outlet for the smoke.

On the bottom of each of the two cell-like rooms of the experimental house were placed 3 large Bunsen-burners, thus alto-

gether 6 burners, in all burning about 1200 cub. ft. of gas in the hour.

The experimental house being dried in keeping at last the burners faintly burning an experiment was made, where the following temperatures were measured:

Experiment begun at 10⁴⁰ o'clock a. m.

11 ⁴⁰	—	- -	730° C
12 ⁴⁰	—	p. m.	900 —
1 ²⁰	—	- -	1000 —
1 ⁴⁰	—	- -	1005 —
2 ⁰⁰	—	- -	1025 —
2 ²⁰	—	- -	1075 —
2 ⁴⁰	—	- -	1075 —
3 ⁰⁰	—	- -	1085 —experim.interrupted.

During an experiment made 2 days later a temperature of about 1000° Centigrade was reached after the course of 5 hours; an hour later the temperature had risen to 1100° Centigrade, which temperature was now kept constant for an hour, and then the experiment was interrupted. The temperatures were measured with *Le Chatelier's* thermoelectric pyrometer during the experiment placed in one of the two horizontal iron-pipes visible in something more than half height on the photographs, the other being only used a few times to control whether the temperature was the same on both sides of the transverse wall. The temperature measured was not maximum temperature, the temperature being apparently higher about 3 courses above the place of measuring.

As it was to be presumed that the attained temperature of 1100° Centigrade was sufficiently high, and that this temperature had been kept constant for a proper time, the experiments were stopped, and one wall of the experimental house was broken down, that the effect produced in the bricks could be observed. The experimental house was broken down in such a way, that the wrong side of the transverse wall became visible, it being presumed that the effect produced in the bricks was observed easier here, because some of the bricks, being not of exactly the same length, projected somewhat here. P. 44 fig. 13 shows the experimental house after the experiment, p. 45, fig. 14 and p. 46,

fig. 15 the same after a part of the outer wall has been broken down so that the wrong side of the transverse wall is visible.

It appeared from the experiment that the bricks were not so much vitrified that the brickwork could anywhere be observed to have settled perceptibly. As to the individual bricks the faces exposed to the fire were observed to vitrify to some extent. As an example it may be quoted that a brick (this is seen in fig. 15 in the 3rd course above the iron-pipe farthest to the left) was vitrified to such a degree, that the cross-sectional areas of the terminal faces were respectively about $14,5 \times 5,0$ cm and about $14,8 \times 5,4$ cm, whilst the cross-sectional area about 4 cm from the terminal faces and farther in was about $15,5 \times 6,8$ cm. The brick was estimated to be one of the bricks that had suffered most, likewise as its projecting much on the wrong side, which is shown by the photograph, suggests the brick having been lightly burnt in proportion to the rest of the bricks, the bricks most lightly burnt being longest owing to their shrinking the least on being burnt.

The manufacturing of moler bricks in Frederiksholm Brickworks is steadily developing. Among new applications may be quoted that about 40,000 bricks have been employed for the new large boilers of Frederiksberg Sporvejs- og Elektricitets Akts. (Frederiksberg Tramway- and Electricity Company) in the new electric station on Finsensvej. On account of the slight thermal conductivity of the bricks they have been employed to the masonry of the »Economizers« and, being so light, for a large, highly situated, horizontal flue. The engineer of the Company, Prof. *Bache* of the Royal Polyt. Inst., has expressed very appreciatively on the bricks for both applications.

As to another application of moler, on which the Laboratory has also made researches, is referred to Section III g.

c. Testing of Sand-Lime Bricks.

Among the examinations of sand-lime-bricks made by the Laboratory those are no doubt of most interest that treat of tests of resistance to frost of sand-lime-bricks, the latter being the subject of the report XV of the

Laboratory. The report was translated in extenso in »Tonindustrie-Zeitung« 1908, Nr. 122 and 125. The following is a summary of the latter.

I. Introduction.

For about 8 years The Danish States Testing Laboratory had employed its usual test of resistance to frost, no complaint being ever brought forward either on part of the brick-manufactories or by the furnishers of natural stones, that this test was too severe. When, however, some years ago the sand-lime-bricks were introduced on our building-market, the Laboratory heard it said, now and then, that its test of resistance to frost must be too rigorous. It was said that in spite of the bricks freezing to pieces at the tests of the Laboratory, they held their own exceedingly well in nature, and the Laboratory was told that bricks, tested with a bad result at the Laboratory, went particularly well through the test of the Berlin Testing Laboratory. Corresponding with the Berlin Laboratory of these matters, the Laboratory sent bricks of a supply whose resistance to frost had been tested here to Berlin. These bricks proved, indeed, to hold their own much better in Berlin than here. An account was already made of these proceedings in the Annual Report of the Laboratory 1906, p. 6. Neither the correspondence carried on nor the experiments made were, however, able to clear up the problem to such an extent, that the Laboratory felt compelled to alter its test of resistance to frost. But on the 26th of June 1907 the Board of Works in Copenhagen issued a notice that only those sand-lime-bricks were to be employed in outer walls the resistance to frost of which had been verified, by which was meant verified at the Laboratory.

A factory of sand-lime-bricks of this place then applied to the Laboratory asking it to make thorough experiments at the expense of the factory in order to substantiate whether the Laboratory did not find it appropriate to alter the test of resistance to frost so that it became more accordant with the Berlin test.

By means of the experiments it should especially be ascertained whether German sand-lime-bricks of the most generally recognized marks were able to go through the test of resistance to frost of the Laboratory.

Further the chief-engineer of the Clay-Laboratory, Mr. *Fischer-Möller*, went to Berlin according to the demand of the same factory to be acquainted with the method followed at the test of resistance to frost here. It became clear to him that the principal difference between the Berlin test and that of the Laboratory was implied in the evaporation from the surface of the bricks being much greater in Berlin than here.

The supposition for real tests of resistance to frost is that the pores of the material that has to be examined are quite or practically quite filled with water. On the freezing of the water its volume is augmented, and then, for one thing, it is dependent on the strength of the brick but principally on the quality of the pores how capable the material is to resist the bursting action consequent to the expansion of the water. When a brick with a temperature of about 20° Centigrade is taken into a room with a temperature of 15° Centigrade below zero, a great evaporation of water will take place from the surface of the brick, and the water left in the brick must then be thought to disperse through the whole volume of the brick. Thus the latter is saturated with water no more and it may even be thought that so much water evaporates that, on the frost finally setting in, the contents of water are so slight that on the whole no bursting action takes place. The easier the evaporation from the surface of the brick takes place, the less rigorous are therefore the test of resistance to frost.

In Berlin the bricks are clasped into straps so that free evaporation can take place from the whole surface. At our Laboratory the method followed at the tests of resistance to frost has always been to place the bricks on the stretcher-sides, partly on the bottom of the freezing-case, partly above one another. Some arbitrariness may be thought to come in here on some of the bricks happening to lie somewhat oftener than others on the bottom of the case, but for common bricks the Laboratory had never found any real occasion for scruples in this respect.

At the General Meeting of the German Union of Sand-Lime-Brick Factories in February 1908 the director of one of the departments of the Berlin Testing Laboratory, Professor *Gary*,

drew attention to the fact¹⁾, that various testing laboratories had come to other results than the Berlin Testing Laboratory as regards testing the resistance to frost of sand-lime-bricks. On this occasion he expressed as his opinion, that presumably this was principally due to the different evaporation during the freezing. He further stated that at the Berlin Laboratory the freezing took place in a rather large room, the evaporation hereby possibly becoming somewhat greater than at other laboratories, where the freezing took place in a smaller case. G. added that presumably the tests of the Berlin Laboratory agreed more with the natural conditions, which always afforded ample opportunity for evaporation. To this our Laboratory begs, however, to remark that it is no easy matter to perceive which test with respect to evaporation is most accordant with the natural conditions. Indeed, the temperature of the bricks in nature is not 20° Centigrade but more probably something very near the freezing point, wherefore the evaporation becomes, of course, much less considerable than during any of the tests; but the bricks are, on the other hand, under natural conditions no doubt very rarely saturated or nearly saturated with water such as it is the case with bricks when being tested.

That it is not only the test of resistance to frost of the Berlin Laboratory and the Danish States Testing Laboratory, which differ, appears clearly from some discussions in a sectional meeting held by the Franco-Belgian department of the International Association of Testing Materials on the 26. of January 1907. Here it was proposed to work at the next congress for a more precise composition of the conference regulations as to tests of resistance to frost, as it had been proved that even if the tests had been executed apparently in the same way at the various testing laboratories i. e. according to the conference regulations, the results obtained often differed very much. During the proceedings Mr. *Mercier* reported that at Laboratoire des Ponts et Chaussées the bricks, whose resistance to frost was tested, were only allowed to absorb $\frac{2}{5}$ of the greatest amount of water, which it was possible for the bricks to receive in a certain manner, the bricks namely being placed in a reservoir, where a partial vacuum was produced; then water was admitted

¹⁾ Tonindustrie-Zeitung 1908, p. 729.

into the reservoir, the vacuum was interrupted, when the bricks had become covered by the water, and after being left in the reservoir for 24 hours they were weighed. It does not appear, however, from the discussions whether these experiments have been made with other stones than natural.

II. Research on Methods of Testing Resistance to Frost.

a. The Resistance to Frost of Sand-Lime-Bricks Tested by Various Methods.

For the tests of the resistance to frost by the various methods 4 different sorts of bricks were employed, namely the factory's own bricks and three sorts of German sand-lime-bricks, *Chem. Laboratorium für Tonindustrie* at Berlin assisting in the procuring of the latter, as our Laboratory had wanted by means of its intervention to secure, as far as possible, sand-lime-bricks from three of the most generally recognised and largest German factories.

In the extracts of the test-register given below the marks of A, B and C comprise the three sorts of German sand-lime-bricks, D the factory's own bricks.

Table V. Result of Compression-Tests with different Sorts of Sand-Lime-Bricks.

Mark of the sort of bricks	Crushing-strength kg pr. sq. cm, mean result for 10 pieces of bricks
A	234
B	243
C	113
D	238

The resistance of these sorts of bricks to compression appears from the above Table V, the compression-tests being executed as usually i. e. the bricks were cut across in the middle and the halves cemented together by means of neat cement mortar into cubical or nearly cubical test specimens.

a. Testing of Resistance to Frost by the Usual Method of the Laboratory.

10 pieces of bricks of each sort were first put 24 hours half, and then 24 hours entirely into water. The bricks then went

through 25 freezings with ensuing thawings. Each freezing lasting at least 4 hours took place at a temperature of 10 to 12° Centigrade below zero, each thawing lasting about 2 hours took place in water of about 20° Centigrade. The outcomes for the individual sorts of bricks follow below.

Sort A.

Each and all of the bricks were damaged, 4 being more severely corroded, 6 displaying a less important or very slight injury.

The bricks, tested for resistance, had suffered too much to be tested for compression.

Sort B.

3 bricks were a little damaged, the other 7 undamaged.

Compression-tests with the bricks that had gone through the test of resistance to frost proved the average resistance to crushing to be 241 kg pr. sq. cm.

Sort C.

8 of the bricks were very much, 2 rather slightly damaged.

No compression-tests could be made, the bricks having suffered too much from the test of resistance to frost.

Sort D.

The bricks No. 1---7 and No. 9 had been very much damaged. The bricks No. 8 and 10 but slightly.

These bricks could not be subjected to compression-tests having suffered too much from the preceding test.

β. Sand-Lime-Bricks Tested as to their Resistance to Frost by Special Methods.

Those tests of resistance to frost of which the question is here, were first undertaken at the factory itself, and then the Laboratory repeated the experiments as a control, and an account is rendered here only of the own experiments of the Laboratory.

They were made with 8 bricks of each sort. The 4 bricks were clasped into iron straps such as it is displayed at p. 51 by fig. 16. Thus free evaporation could take place from all the surfaces of the bricks. To keep them separated small

pieces of wood were employed. On observing by one of the experiments some splits broken off, which might possibly be due to the swelling of the wood, caoutchouc strips were used instead of pieces of wood. The other 4 bricks were not clasped into straps, but placed in the freezing case, one header-side standing directly on the bottom of the freezing case. There was taken care to place these bricks continually with the same header-side turned down-wards. For the rest the tests followed the same line as usual.

Sort A.

1) *Clasped into straps.*

The bricks had apparently not been damaged.

2) *Standing on one header-side.*

In all bricks the header-side turned downwards had been quite frozen off, in 2 of the bricks some other injuries were also observed.

Sort B.

1) *Clasped into straps.*

In one of the bricks was observed an inconsiderable disruption of the shell in a corner of the header-side turned downwards. The other bricks had apparently not been damaged.

2) *Standing on one header-side.*

One of the bricks displayed smaller disruptions of the shell in two corners turning upwards. These disruptions were continued somewhat down the adjacent stretcher-sides. The other bricks had apparently not been damaged.

Sort C.

1) *Clasped into straps.*

3 of the bricks displayed very severe damages on the header-sides turning downwards, in one brick the whole header-side being practically absent, in another the two thirds, in a third the half-part. In a fourth brick a less considerable disruption of the shell in two corners of the header-side turning downwards was observed.

2) *standing on one header-side.*

On all bricks the header-sides turning downwards were frozen off at a thickness of about 1 cm, and apart from this all bricks displayed other very considerable damages.

Sort D.

1) *clasped into straps.*

The bricks had apparently not suffered the least

2) *standing on one header-side.*

In all bricks the header-sides turning downwards were quite frozen off, there were besides some other damages, smaller or larger, to be observed in all the bricks.

In the present figures among which fig. 17, p. 53 shows B-bricks, fig. 18, p. 54 C-bricks, fig. 19, p. 55 D-bricks, that row of bricks off which is written X consists of some of the bricks that have been clasped into straps, the row Y of some of the bricks that have stood on one header-side and the row Z of some of the bricks the resistance to frost of which has been tested according to the usual method of the Laboratory. For B the row of Z is absent, these bricks, as it appears from the register, having gone through the compression tests after the tests of resistance to frost.

b. *Common Bricks Tested as to their Resistance to Frost by all the Methods.*

The above named experiments had substantiated that the common test of resistance to frost of the Laboratory was much more severe than the test by which the bricks were clasped into straps, the latter coming much nearer to that of the Berlin Laboratory. Whether the changed test were quite congruent with that of the Berlin Laboratory could not be made out; in that case the loss of weight taking place in both places during the freezing and due to the evaporation ought to have been substantiated. But it had become apparent that generally recognised¹⁾ German manufactures could not stand the test of resistance to frost of the Danish States Testing Laboratory.

The Laboratory learning at the time, when these experiments were being made, that considerable piles of bricks from the demolished Castle were lying at Christiansborg,

¹⁾ Here the remark must, however, be inserted that even if the C-bricks are to be counted among generally recognised manufactures, the bricks tested at the laboratory cannot claim this title, not even meeting the minimum demands on resistance to compression of the German Union of Sand-Lime-Brick Factories.

and that these bricks were very often freezing to pieces, the thought very naturally struck the Laboratory of making these bricks go through the same tests as those made with the sand-lime-bricks, especially in order to discover, whether it was conceivable that bricks, which freeze to pieces in nature, could stand the strap-tests.

The bricks were taken from a large pile of bricks derived from the demolished Castle. Many of the bricks in this pile had frozen to pieces. The bricks were well burnt, their internal structure being, however, as a rule rather heterogeneous.

α. Testing of Resistance to Frost by the the Usual Method of the Laboratory.

This test was made on 4 bricks, 2 of the bricks had been extremely damaged, whereas the two were apparently quite undamaged.

β. Testing of Resistance to Frost by the Special Methods.

1) *clasped into straps.*

After 25 freezings all the 4 bricks were apparently quite undamaged.

2) *standing on one header-side.*

2 of the bricks had suffered very much, 2 to a certain degree.

Then the 6 hitherto undamaged bricks were subjected to the usual test of resistance to frost, namely all the bricks, that had been clasped into straps and the two of the bricks from the usual test of resistance to frost. The 4 first named bricks were designated A, B, C and D, the 2 latter E and F.

A, B and C proved to be very much damaged, whereas D, E and F were apparently quite unhurt.

III. Discussion of the Results of the Experiments.

As it according to the above seemed at any rate very probable, that bricks could stand the strap-tests without really being able to resist frost, a new difficulty had been placed before the Laboratory. Hitherto had been considered only the possibility to introduce a new somewhat more lenient test, namely the strap-test, and leave it to the requirers themselves to decide whether they would prefer the more rigorous or more lenient test. But

now the point of view taken by the Laboratory was more likely to be, that common bricks should go through the older test, the strap test yielding no guarantee for the material being able to resist frost. The result of the last experiments could, on the other hand, also be interpreted in the way that these strap-tests did not, on the whole, yield any guarantee for any material being able to resist frost, so that, perhaps, in the long run it would become apparent that materials acknowledged to be able to resist frost according to this test, froze to pieces nevertheless in nature.

Thus, this question again arose as it had over and over again during the foregoing experiments viz., where is the great difference between sand-lime-bricks and common bricks in consequence of which a plain common brick can be placed directly on the bottom of the freezing-case without being damaged, while as a rule the best sand-lime-bricks are damaged to a great extent.

Certainly, it had been clear, that the internal structure of the two materials differed somewhat, sand-lime-bricks consisting chiefly of sand-grains cemented together by calcic-hydrosilicate or the like, so that the rather large cavities between the grains communicate by comparatively narrow outlets, the bricks on the other hand of a material either quite porous i. e. furrowed by many canals or for the very sandy bricks of sand-grains cemented together by a porous mass, but one had not been able to explain the different action of the frost in sand-lime-bricks and common bricks. — The Laboratory being, however, confident of having gained a clear understanding of this problem, an account will be rendered below of the considerations made and of some experiments which seem to prove the correctness of these considerations.

In a sand-lime-brick generally more than 90 per cent (by weight) of the whole brick will consist of sand-grains i. e. a material not at all porous. In the intermediate spaces a material will occur the porosity of which is not thoroughly known, but is probably not very great, and the mass of which is at any rate exceedingly slight as compared to that of the sand, and there will also occur cavities presumably much fewer in number and at the same time considerably larger than the pores in a common brick, the capacity of absorbing water and specific gravity generally not differing very much in common bricks and sand-lime-bricks. In

a common brick of very sandy material size and number of cavities will very likely be very much the same as in the sand-lime-bricks, but there is however this principal difference, that in sandy, common bricks there are not only cavities between the grains but the latter consist of sand-grains imbedded in a very porous material. In such a material as sand-lime-bricks it is easily conceivable that it is of rather great importance whether the cavities are filled with water or not on the frost setting in. If full of water it will be very difficult for the ice, owing to the narrow outlets of the cavities, to expand without the surrounding sand-grains, in themselves quite impenetrable to the ice, getting displaced.

For the common brick the case differs somewhat. Supposing that the structure of the brick is quite homogeneous, the water on freezing and then expanding will easily find its way through the porous material of the brick. But the homogeneity being deficient, the supposition for the water (the ice) dispersing all over the brick is broken, and conditions are thus quite changed. But of this an account will be rendered below.

The Laboratory has, for the rest, not examined thoroughly the shape of the cavities in sand-lime-bricks or of the pores in bricks, so that the above named is more particularly based on considerations, which seem apparent according to the general knowledge of the producing of the named materials.

The natural conclusion from these considerations is, that the capillary attraction must be considerably greater in bricks than in sand-lime-bricks and this conclusion has been strengthened by the experiments, which follow below¹⁾. For these experiments were taken 2 sorts of red bricks A and B and 2 sorts of sand-lime-bricks C and D²⁾, 3 pieces of each sort. The bricks were dried till their weight was constant, and then weighed. They were thereafter placed in a

¹⁾ A few months after these experiments had been made the Laboratory learned that under a discussion in *Transact. of Americ. Cer. Soc.* IX 07, 693 it was maintained by Prof. *Wheeler* that regular pores are of decisive importance to the resistance to frost in bricks, and that the rapidity with which water is absorbed by the bricks on these being partly immersed is thought to give a measure for the resistance to frost (*Tonindustrie-Zeitung* 1908, p. 873).

²⁾ The designations of C and D employed here have no connection with those employed in Section II.

tray where there was water up to a height of 2,5 cm, and at intervals of one hour it was observed how much the water rose in the bricks; the bricks were also weighed after 7 and 24 hours. The curves at fig. 20, p. 59¹⁾ show graphically the average height which the water had attained in the 4 sorts of bricks.

The facts stated here explain several hitherto obscure phenomena. Abiding by the above named experiments it becomes clear, for instance, why the C-bricks, clasped into straps, which were said to have neither frozen to pieces in nature or when tested in Berlin, displayed some disruptions of the shell and just on the header-side turning downwards, on being tested at our Laboratory. This is namely explained in that the water, because the capillary attraction was not strong enough to keep it up, has sunk down to the bottom of the bricks, the lower parts of these thus becoming overfilled with water as compared with the upper parts. This becoming less apparent by the tests of resistance to frost in Berlin can be explained in that the bricks in Berlin were clasped in a lying position and here standing up. It may be objected that bricks tested by the older method of the Laboratory also display disruptions of the shell on the header-side and lower bed these having not touched the bottom of the ice-case. Disruptions of the shell occurring nevertheless is due to the above named overfilling of the pores in the nether parts of the bricks. Hereby first one part of the lower bed and the header-side is damaged. Next time when the brick has come to lie on the other stretcher-side, the other part of header-side and lower bed is overfilled.

Another fact, which might seem to speak against the importance of the capillary attraction, is that appearing in those bricks which have been standing on a header-side, these also displaying some disruptions of the shell elsewhere than in the nether part of the brick. It must, however, be remembered here that the bricks may partly come in contact with the sides of the ice-case, partly with one another; this will, of course, principally be the case, when the bricks have suffered so much on the header-sides turning downwards, that they are shaking to and fro. If clasped, no other disruptions of the shell would hardly have been observed than those in the nether parts of the brick (the corners excepted, see below). In the bricks clasped into straps disrup-

¹⁾ In Fig. 20 the word »Timer« means hours.

tions of the shell were, in fact, only observed on the header-side turning downwards, in so far as the bricks were, on the whole, damaged.

It must then be supposed, that the damage is due to a prevention of the free evaporation from the surface combined with a small capillary attraction. This is also confirmed by the fact, that bricks which have not at all touched the bottom of the freezing case, but only been lying on the other bricks may suffer rather much.

The Laboratory has later on made a great many similar experiments as regards the capillary attraction in common bricks and sand-lime-bricks. For the former accordance with the above named experiments was constantly substantiated. But among the sand-lime-bricks a few bricks were now and then found where the capillary attraction was rather considerable. In a single case 3 bricks of the same sort displayed a strong capillary attraction. These bricks then were subjected to the usual test of resistance to frost of the Laboratory. This latter did not produce any disruptions of the shell in the planes themselves, but in all bricks the corners were more or less damaged. The said bricks displayed, for the rest, a resistance to fracture which is rather low for sand-lime-bricks, namely 124 kg pr. sq. cm. Probably the corners were specially fragile (besides, only 7 of 10 bricks were able to stand the changed test of resistance to frost of the Laboratory).

The corners seem, on the whole, to be a specially weak point in the sand-lime-bricks. This cannot seem strange, however, when it is borne in mind that it is claimed here that a brick with sharp corners shall be pushed out from the mould in a state, where the mass of the brick is not only quite soft but also practically unelastic. The great friction at the corners quite naturally causes a weakening of the coherence between the outer shell of the corners and the other part of the brick which under normal conditions is only the case to a very slight degree in bricks.

The Laboratory does not maintain that a great capillary attraction yields a guarantee for the resistance to frost in a brick or sand-lime-brick. With reference to what has just been said, it can especially very well be imagined that a brick loses its cor-

ners during the test of resistance to frost in spite of its displaying a strong capillary attraction. Finally, it cannot be taken for granted that because the water is moving easily in a brick, the same should be the case with the ice.

A study of the shape of the cavities would certainly give valuable informations in this respect.

There remains to explain why well burnt bricks under certain circumstances can stand the »strap test« but not the usual test of the Laboratory.

As already mentioned this must be due to deficient homogeneity in the bricks concerned.

This want of homogeneity may of course assert itself in many ways, and it would be too long to account for the modes of expression of this want in its various shades.

But in the following we shall try to explain how absence of homogeneity can become apparent in different ways under the various tests of resistance to frost and in nature when acted upon by the frost.

Let us, for instance, imagine that fig. 21, p. 62 shows a brick produced by a material, sandy in itself, but where owing to deficient working there is a stripe A of not sandy material. We further imagine that the brick has been burnt so hard that the very clay-substance has become vitrified while the sandy material is as yet rather much absorbing.

We shall now see how such a brick will stand actions of frost in the following 3 cases:

- 1) The usual test of the Laboratory.
- 2) The »strap test«.
- 3) Frost in nature.

1) We now fancy that the brick is placed on the bottom of the freezing case with the stretcher-side B turned down. Evaporation from the side B thus becoming impossible, the water will try to rise through the brick, but here it meets the stripe A not allowing of transition of the water. Then the consequence is that the shell situated between A and B is pushed off.

2) On the same brick being, however, clasped into a strap, so that free evaporation can take place from all the planes of the brick, it will in all probability not be the least damaged.

3) We now presume the brick thus masoned in that the side B is front side, further that the surface of the wall where the brick is placed faces south-west. Let us imagine that for some days it has been a storm from the south-west and rain. The shell situated between A and B has then become saturated with water by and by, the stripe A preventing the water from penetrating further into the brick. If now it becomes dry weather again for some days with a temperature above the freezing-point the greater part of the water will evaporate and the brick not be damaged. But on the weather changing suddenly to some degrees of frost while the brick is dripping wet, an ice-shell will form outside the brick preventing further evaporation of the water in the shell between A and B. All the water in this shell will freeze in consequence of which the shell is easily blown off or its coherence with the other part of the brick so much weakened, at any rate, that a repetition of the named treatment conveys a disruption of the shell.

Something very like may for the rest take place when such a brick is standing in a pile in nature.

Let us imagine, for instance, that the same brick is standing uppermost in a pile of bricks the stretcher-side B turned upwards and other bricks on the sides of it. Through a longer period it has been raining or perhaps snowing with ensuing thaw. The shell between A and B has become saturated with water. The spaces between the brick and its neighbouring bricks are filled with amnions or melting thawy snow. The weather suddenly changes to frost, and the shell between A and B is loosened.

At fig. 22, p. 63 is given a transverse section of an exceedingly heterogeneous brick, partly frozen to pieces, and derived from one of the piles on the building place of Christiansborg. It is distinctly seen how the disruptions, due to the frost, follow the structure in the brick.

As mentioned above there may, of course, be many various forms of heterogeneity not necessarily alone due to deficient working of the clay, but also to other reasons. A deficient burning may, for instance, produce »over-fired« bricks i. e. such where the surface is much harder burnt than the heart of the brick. Also this sort of heterogeneity will be able to occasion the destruction of the brick when acted upon by the frost.

From that which has been put forth here and perhaps will

be termed a theory by some people, but is, however, effectively borne out by the experiments made with the bricks from Christiansborg, it will appear comprehensible that the Laboratory does not see any reason for changing the test of resistance to frost for common bricks (or at any rate only for changing it thus far that the bricks will be placed alternately with the header-sides or stretcher-sides resting on the bottom of the freezing-case), and the less so as this test has never called forth any complaint neither on the part of the brick-manufactories nor from master-masons and architects.

Every impartial looker-on will admit that for sand-lime-bricks no great risk is run of finding these sorts of heterogeneity. But one might, perhaps, be inclined to believe that as the capillary attraction is less in sand-lime-bricks than in common bricks, the evaporation from the surface must also be essentially less.

On making, however, comparative experiments in drying common bricks and sand-lime-bricks, this was not proved to be the case during the first four days and nights of the drying. The determination of the capacity of drying of the bricks was made in the following way:

The bricks employed for the determination of the faculty of absorbing water were saturated with water and laid up in two rows in the laboratory, the bricks being placed on lists. The spaces between the individual bricks were everywhere the same. To equalize matters as much as possible for all the bricks, a brick saturated with water of the same sort as those being examined was placed at the ends of each row, without being, of course, weighed. At proper intervals the bricks were weighed. After being air-dried till their weight was constant, they were at last dried at a temperature of about 100° Centrigade till their weight was constant.

As it appears from Table VI an average increase of weight of 0,5 per cent takes place for the sand-lime-bricks while being saturated with water and dried, but for the bricks an average decrease of weight of 0,1 per cent. In the graphical sketch of the drying, no regard has, however, been taken of this; see fig. 23, p. 66.

The evaporation from the surface of the brick saturated with water or at any rate very wet

does not seem to differ very much in common-bricks and sand-lime-bricks, and it is this matter, which is of importance to the problem before us.

Table VI. Average Weight in g for all the 10 Bricks tested.

	Dried at about 100° before being saturated with water	Saturated with water	After being dried in 26 days and nights	Dried at about 100° after being saturated with water and dried
Sand-lime-bricks	2562	2896	2669	2574
Bricks	2263	2602	2264	2261

Similar experiments made at the Berlin Testing Laboratory have given the same result; cp. *Burchartz*: Die Prüfung und die Eigenschaften der Kalksandsteine, Berlin 1908, S. 89.

The Laboratory does not, however, agree with Mr. B. in that it is principally due to a chemical process, the transformation of the calcic hydrate to carbonate of lime, that the sand-lime-bricks after being dried do not return to their original weight. In that case the greater part of this augmentation of weight would not disappear on the bricks being heated to 100° (cp. Table VI). The Laboratory is, on the contrary, of opinion that on the sand-lime-bricks retaining the water in the cavities to a much higher degree than the bricks, this difference is not due to casualties but to the different quality of the cavities of the bricks.

IV. Conclusion.

The evaporation from the surface of bricks, saturated with water or very wet, being not less for sand-lime-bricks than for common bricks and the capillary attraction being as a rule apparently considerably less, there is presumably no reason for maintaining a test the severity of which for the sand-lime-bricks is principally due to matters which cannot be seen to be of any importance in nature.

The Laboratory is, certainly, inclined to think that the bricks as regards the corners (cp. above) have the advantage of the sand-lime-bricks, but this advantage will show itself sufficiently clearly by the new test.

On account of the experiments made, and reliable informations as to sand-lime-bricks freezing to pieces in nature being constantly absent, the Laboratory has found it appropriate no more to maintain a test which at any rate seems to be too rigorous, as sand-lime-bricks hardly will be employed in such places where they can be exposed to frost when saturated with water¹⁾).

That under such conditions they should yield the same resistance to frost as good well burnt bricks the Laboratory does not think.

As to the carrying out of the test, the laboratory has altered the form of the straps, as showed on fig. 24, p. 67. The sand-lime-bricks are clasped here as in Berlin in a horizontal position. By the shown construction of the straps is obtained, that there can be place for two straps with 5 bricks each in a freezing-case, while by the former construction there might be only 1 strap with 4 bricks in a freezing-case.

d. Testing of Cement-Bricks.

Of late years no slight industry for the producing of cement bricks has sprung up in Denmark. This industry seems, indeed, to be rather natural for the country. The Laboratory has therefore published a Report XIV on experiments with these bricks. Up to the 1st of April 1909 the Laboratory has tested 26 sorts of bricks, both with and without mortar depressions. Only in 2 cases the crushing strength (the average numbers) attained 100 kg pr. sq. cm being in most cases far below. The average crushing strength of the 17 sorts of massive bricks tested, of which have been tested at least 10 pieces of bricks, is 58 kg pr. sq. cm and for the corresponding 9 sorts of bricks with mortar depressions 55 kg pr. sq. cm.

As to the tests of resistance to frost the cement bricks proved to be by no means equal to burned bricks, as each well-burnt brick can with certainty be considered able to stand the test of resistance to frost whilst none of the cement bricks tested went

¹⁾ The more lenient tests of the Laboratory for sand-lime-bricks has been criticised in *Tonindustrie-Zeitung* 1908, Nr. 149 a criticism which has been disproved by the director of the Laboratory in the same Nr.

through it. It must, however, be observed that the Laboratory has later changed its test of resistance to frost for sand-lime bricks — see under c — and intends possibly to introduce this changed test also for cement bricks.

During the last year there has been required commenced by the Laboratory a longer series of experiments with producing of cement-bricks in different proportions while employing various sorts of cement and sand. The producing of the bricks was made at different times of the year (also in order to substantiate the influence of the season on the strength of the bricks) at a cement-brick-manufactory in Jutland controlled by the Laboratory, while the compression-tests of the experimental series produced were made at the Laboratory at certain intervals. The experiments are still continued.

e. Testing of Clay- and Cement-Pipes as to their Resistance to Pressure from without.

The tests made by the Laboratory on this line and on which Report XIII¹⁾ was formerly published were with very few exceptions executed after the method recommended by the International Congress of Brussels in 1906 after proposal of Prof. Gary, the pressure having at these experiments been working along single generators, and only these experiments appear in the following tables.

For these tests the Laboratory employs the *Tinius Olsen*-machine — see Report I — when the inward diameter of the pipes does not exceed 6" (16 cm); for pipes of this dimension there is still room here.

The apparatus of the Laboratory for testing of pipes where the diameter exceeds 6" is a lever as shown at p. 69—70 by fig. 25—27. R — see p. 69 fig. 25 — is a frame of -iron founded into a very large concrete block K. The frame consists of 2 pieces of perpendicular -iron connected above by a short piece of horizontal -iron to which is secured by bolts an edge-pillow P. Against this edge-pillow the lever V itself bears with its one knife-edge.

The lever is a wooden beam into which are let 3 steel-plates

¹⁾ A summary of this report is to be found in *Tonindustrie-Zeitung* 1907, p. 1695.

s; in the first is placed the named knife-edge of the lever bearing against the edge-pillow of the frame, in the second the knife-edge which transfers the pressure to the pipe and in the third a bolt furnished above with a center-mark for the applying of the scale with the weight. It has namely been considered appropriate not to suspend the scale on a knife-edge but to use a suspension shown on a somewhat larger scale at p. 70 in fig. 26 and 27. In the steel-plate s is an oblong hole in which the bolt b can be displaced in the longitudinal direction of the lever and then be fastened, so that it is possible to attain that the proportions remains continually 1 : 10 even if the length of the wooden beam should be somewhat changed in drying up or swelling.

In the bolt head b is the center-mark where the taper of the link B is applied. In the link the scale is suspended as shown in fig. 25 and 27.

The loading is made by means of weights or by pouring water into a bucket placed on the scale.

With this apparatus can be tested pipes where the outward diameter is up to 32" (84 cm).

As indicated at p. 69 in fig. 25 the pipe is during the test placed on a block O of pieces of beams and planks placed on the concrete foundation K. The pressure is transferred to the pipe through a piece of beam Q to the top of which is screwed a piece of iron-plate where the knife-edge can touch.

Between the block and the pipe as well as between the piece of beam Q and the pipe is placed a piece of felt of a thickness of about 15 mm in order to spread the pressure as evenly as possible over the whole length of the pipe. During the test the pipe is placed in such a way that the whole length except the socket is exposed to pressure.

As results of crushing-tests with clay- and cement-pipes, as far as the knowledge of the Laboratory goes, have only been published from few quarters, the Laboratory will here give all results obtained until the 1st of July 1909.

In the Table VII below is given the result of the crushing-tests with all clay-pipes tested up to the 1st of July 1909. In Table VIII occurs the result of the crushing-tests made with cement-pipes up to the same date. The sign { means that two or more pipes of the same dimensions were sent in and tested at the same time.

Table VII. (Clay-Pipes.)

External length	External length to the socket	Internal length to the socket	Internal diameter	Thickness of material	Crushing-strength	
					Total	kg pr. sq. m of horizontal cross sectional area
mm	mm	mm	mm	mm	kg	
660	562	588	112	15	956	11980
680	582	608	120	16	819	9230
680	588	621	116	16	1006	11600
687	582	606	113	15	703	8390
667	567	588	117	16	1116	13170
641	543	575	154	20	1814	17210
628	539	582	154	20	1358	13000
719	628		150	18.4	1653	14100
857	765		150	18.4	2207	15340
680	582	615	150	19	1713	15250
673	575	615	150	19	2255	21190
673	575	602	147	19	2212	21590
703	618	657	157	19	1668	13760
703	618	654	157	19	2111	17420
654	575	602	157	18.6	1909	17150
680	588	628	144	18.9	2394	22300
654	575	602	150	15.9	982	9400
687	598	628	157	17	1275	11250
677	585	618	154	17	1267	11380
677	588	621	154	17	1237	11310
863	758		248	21.7	1340	6040
667	579	615	229	19	1263	7080
667	575	615	229	19	918	5150
680	575	611	298	25	1618	6870
677	582	611	301	26	1703	7090
673	579	624	324	25	1352	6210
687	585	631	320	25	1272	5790

Table VIII. (Cement-Pipes.)

673	608	638	105	20	1713	19760
673	605	638	105	20	1805	21050
680	615	647	154	23	867	7040
693	592	660	170	22	1170	9130
673	562	634	157	22	1195	11130
673	562	634	157	21	1058	9940
673	562	634	157	21	1300	12210
673	562	634	157	21	1141	10710

External length	External length to the socket	Internal length to the socket	Internal diameter	Thickness of material	Crushing-strength	
					Total	kg pr. sq. m of horizontal cross section- al area
mm	mm	mm	mm	mm	kg	
677	602	628	157	24	1410	11360}
677	602	634	157	24	1585	12770}
680	598	628	154	26	1405	11320}
680	602	628	154	26	1122	8970}
680	602	628	154	26	1220	9750}
693	588	654	170	22	1862	14760
700	595	660	170	22	1463	11420
700	595	660	170	22.5	1492	11650
647	549	608	154	21.5	664	6180
651	549	615	154	21.5	951	8860
677	598	628	157	21	699	5860}
680	598	634	157	21	1070	8980}
680	605	641	157	24	1721	14090
641	536	602	150	22	1258	11930
647	549	611	150	22	1187	11050
	602		157	24	807	6550
	602		157	24	685	5560
680	602	634	157	23	1031	8440
680	602	631	157	23	1063	8700
657	608	631	157	23	1007	8180
700	592	660	167	22	1031	8110
665	590	620	155	25	1453	12010}
665	590	620	155	25	1283	10600}
670	575	615	150	28	1270	10510}
660	575	620	150	28	1511	13140}
820	740	780	230	27	1503	7130}
820	735	780	230	32	1473	6910}
835	750	800	230	28	3123	14610}
835	750	800	230	28	2283	10680}
798	700	772	229	25	2385	12420
811	706	772	229	26	800	4060
811	706	772	229	26	970	4920
840	752	788	235	25	1403	6530
840	749	798	235	25	1612	7510
840	752	804	235	27	732	3360}
837	752	794	235	27	961	4410}
811	700	768	229	25	1359	7070
837	752	791	209	26	1286	6560
837	752	791	209	27	1424	7190
843	745	798	262	32	1381	5700
843	745	798	262	33	1270	5200

External length mm	External length to the socket mm	Internal length to the socket mm	Internal diameter mm	Thickness of material mm	Crushing-strength	
					Total kg	kg pr. sq. m of horizontal cross sectional area
847	739	785	317	31	626	2230}
843	739	798	317	31	870	3100}
817	703	772	304	28.5	1072	4220
850	745	791	307	32	1481	5350}
850	745	794	307	32	1563	5640}
840	739	804	314	32	1882	6650}
840	742	804	314	33	2332	8220}
873	732	785	314	35	1434	5090
863	732	794	314	35	1285	4560
824	752	791	317	34	1225	4230
845	750	800	310	35	963	3380}
845	750	800	310	35	1063	3730}
863	732	817	396	35	1252	3660
843	752	791	376	34	819	2480
817	693	768	379	33	841	2730
837	729	788	389	35	1024	3060
820	700	770	375	35	1603	5150}
820	700	770	375	35	1673	5370}
830	715	765	380	45	1893	5630}
835	735	780	375	47	1783	5160}
855	740	800	470	46	1493	3600}
860	745	805	470	46	1123	2690}
820	700	770	450	39	1433	3860}
820	700	770	450	39	2043	5510}
1007	879	942	471	40	1396	2880
853	732	798	471	39	1406	3000
850	732	798	484	39	1544	3280
853	739	794	471	38	753	1860}
853	739	794	471	38	764	1890}
900			549	78	1633	2570}
890			549	78	2353	3750}
961	876	955	553	50	2829	4950
961	883	948	553	54—51	2038	3520
994	883	951	543	50	1016	1800
857	749	811	536	46	1638	3490}
857	749	811	536	46	1680	3570}
1004	896	945	628	55	1608	2430}
1007	902	948	624	55	1870	2820}

It will be seen that in the Tables beside the dimensions of the pipes and the total crushing-strength is also given the crushing-strength in kg pr. sq. m horizontal transverse section, where the horizontal transverse section is calculated as the product of the external diameter and the external length of the pipe to the socket.

The pipes treated of in Table VII and VIII were all common round pipes with sockets. Only in a few cases the proportions and the age of the pipes tested were specified.

It is, however, to be presumed that the pipes were not sent in to be tested until they were considered fit for use i. e. have been stored for a sufficiently long time for hardening.

It is seen that the number of pipes tested with other dimensions than 6" = about 160 mm is but small, so that the results cannot be said to give any satisfactory picture of the strength, that can be claimed for other pipes than the 6" ones.

But of these not few were tested, namely 15 pieces of clay-pipes and 31 pieces of cement-pipes. Thus, it is only for the 6" pipes that the end has been attained aimed at by the Laboratory in publishing the results, namely, both that a furnisher on having his pipes tested shall be able to find figures to compare with those found out for his own pipes, and that the figures shall be of use for the drawing up of specifications in giving an idea of what can be claimed. The mean crushing-strength for 6" clay-pipes is 15,400 kg pr. sq. m and for 6" cement-pipes 10,030 kg pr. sq. m horizontal transverse section.

f. Attempts at Producing Weather-Proof Cement-Plaster without Fissures.

These researches were made for a committee appointed by the magistracy of Copenhagen in order to find out how the decoration of *Thorvaldsens Musæum* in Copenhagen could be restored. This decoration consists partly of large fields of one colour, chiefly yellow, but also black, green or white, partly of a series of pictorial representations in many colours on the outside of the museum representing the return of Thorvaldsen to Copenhagen and facing the court in few colours representing leafage, palms, driving genii, decorated vases etc. The pictorial representations are executed as inlaid

work of coloured cement. The uniform fields also chiefly consist of coloured cement, the yellow fields having, however, a layer of fresco-paint above the coloured cement. Here and there occur for the rest blue and red lines, friezes and lists round the fields.

The named yellow paint has come off or has grown incoherent. When moistened with water the whole of the yellow layer of plaster can be removed with a spatula which cannot be done for instance with the black layer of plaster when moistened. Below the yellow paint the yellow coloured cement is in many places seen to have nearly lost its colours. The pictorial representations have also to a great extent lost the colours; all round the coloured plaster is seen to be disintegrated, and everywhere the cement plaster both in the fields and the pictures is full of cracks. It may be taken for granted that the latter have contributed to the principal destruction of the plaster planes in the course of time; water and dirt penetrated into the fissures, and on the freezing of the water they widened out, while the dirt occasioned the formation of fungi in many ways instrumental in the plaster and colours being ruined.

It is well known that the fissures are derived from the contraction of the cement plaster during the setting. Before the Congress for testing materials in Paris in 1900 Prof. *Henry Le Chatelier* laid the results of a series of experiments begun by him some years before on the shrinkage of the absolute volume of cement mortar during the setting and shortly before published in *Bull. de la Soc. d'Encouragement* 1900, p. 54. Before the same Congress the director of the Danish States Testing Laboratory laid some experiments made by the Laboratory partly to show this contraction, partly to prove that the contraction could be counteracted when treating the plastered planes with Kessler's Magnesia-fluate¹⁾. The Report VI²⁾ of the Laboratory treats, however, not only of these matters, but also of several others, thus, researches on the alkalinity of various sorts of cement and researches on the best reaction against this alkalinity. Among the remedies tested for this purpose fluuate proved to be best adapted

¹⁾ Last Volume of the Report of the Congress, p. 183, Summary of a Report by *G. A. Hagemann* and *H. I. Hannover*.

²⁾ Translated into German in »Baumaterialienkunde« 1903, Nr. 12 and 1904, Nr. 7, 8 and 11—12.

to coloured cement planes, being at the same time instrumental in rendering the plaster tight. The named report treats further of the researches made by the Laboratory to find suitable pigments to mix up with cement mortar, as it is well known that many pigments are destroyed by this intermixture.

The researches were made at the Testing Laboratory by a sub-committee consisting of the gentlemen named in Note 1, p. 167, and elected by the committee, and this sub-committee had various restoring experiments made on loose flakes, among these in the spring of 1900 a larger sample of the pictorial representation containing 8 various sorts of coloured plaster. This sample was able to stand all through the summer in sunheat and rain without cracking and, it is true, that in the following winter a great many very fine fissures occurred in 3 of the 8 sorts of coloured plaster, but the 5 others were exposed to the sunshine and rain of 3 summers and the frost of 2 winters i. e. to up to about 50° Centigrade and down to 12—13° Centigrade below zero without cracking and without the named fine fissures increasing apparently in number or size.

A restoring trial was later made by the magistracy of Copenhagen by much the same method on the museum itself at the ordinary entrance. But bad fissures soon occurred here. The reason can be sought for in various circumstances, for instance in the intermixture of pigments having not been the same, in the hardness of the smoothing having differed, or in some contraction of the decoration having taken place while the experiment was made with the loose flake, this not having been discovered by formation of fissures, because perhaps the flake itself has also contracted. The very difficult problem has therefore not yet been solved, but in one direction, at any rate, there seems to be a reliable result, as series of durable pigments having namely been found.

**g. Experiments with Partly Replacing Lime in Lime-Mortar
by Moler.**

At the first series of experiments a mortar was begun with which contained 8 per cent dry calcic hydrate. As sand was used a mixture in equal proportions (by weight) of normal sand and down sand. In the named mortar the half-part of the calcic hydrate was then replaced by moler.

Compression-test-pieces were formed, as usually on *Böhme's* hammer apparatus. After being left 28 days in a very moist room — the degree of moisture in this room was later determined to be about 90 per cent — the test pieces were subjected to the compression-test. The results are seen in Table IX.

Table IX. Compression-tests with Lime-Moler-Mortar.

Proportions	Mortar A	Mortar B
	8 per cent calcic hydrate 92 per cent sand	4 per cent calcic hydrate 4 per cent moler 92 per cent sand
mean for 10 test-pieces	3,0 kg pr. sq. cm	31,8 kg pr. sq. cm

Thus, it is seen that the strength increased exceedingly much when replacing half of the calcic hydrate by moler. As it appears, however, from the next series of experiments, conditions during the first series of experiments were rather unfavourable to the lime-moler mortar in that the storing took place in a very moist room.

At the second series of experiments a mortar was begun with containing 5 per cent dry calcic hydrate.

The sand employed was a sort of wall sand, the lime was bought in the market.

In the named mortar the 3 per cent calcic hydrate were then replaced by moler.

Ten test-pieces of each mortar were produced. Of these 10 test-pieces 5 were placed in a very moist room, the other 5 on a

Table X. Compression-tests with Lime-Moler Mortar.

Proportions	Mortar C		Mortar D	
	5 per cent calcic hydrate 95 per cent sand		2 per cent calcic hydrate 3 per cent moler 95 per cent sand	
	Stored in very moist room	Stored in the cement premises	Stored in very moist room	Stored in the cement premises
mean for 5 test-pieces	1,9 kg pr. sq. cm	6,0 kg pr. sq. cm	5,1 kg pr. sq. cm	4,3 kg pr. sq. cm

shelf in the cement premises. The result of the compression-tests after 28 days appears from Table X above.

It appears from this that while the moler mortar increases at any rate a little in strength when left in a very moist room instead of in comparatively dry air the very opposite is the case with the unmixed lime mortar which after 28 days has attained a crushing strength 3 times as large when stored in comparatively dry air as when preserved in very moist air. The figures further show that in a mortar with 5 per cent calcic hydrate about half of the latter can be replaced by moler without the strength particularly decreasing in a room where the degree of moisture is that of the cement premises — and the degree of moisture is here about 65 per cent — while in a very moist room much is gained in strength on employing moler in the named quantity.

The named 2 mortars were further employed for adhesion experiments.

The Laboratory had formerly made adhesion experiments in the well known way of masoning together crosswise 2 bricks and then pulling them from each other after the lapse of a certain time. To pull them away from each other the primitive apparatus, shown at p. 78 in fig. 28, was employed supplied with some small screws indicated in the figure and recommended by *v. d. Kloes* in »Baumaterialienkunde« 1900, p. 154.

S are the bricks seized by claws *K* the uppermost of which is suspended in a dynamometer again fastened to the beam *D*. The lower claw is pulled downwards when a man turns by hand the shaft *A*, and another at the same time pulls the free end of the rope *T* wound some times round the shaft *A*. The shaft is turned by means of a small fly-wheel attached to it.

This apparatus has proved appropriate in several cases, the shaft *A* belongs to an extant machine and the trestles *B* can be placed, as shown on the figure, on both sides of the shaft and the controlled dynamometer *M* where the pull exercised for the overcoming of the adhesion is displayed.

In the case before us the adhesion experiments were, however, made in the following well known way:

Common bricks were employed; they were masoned together 3 and 3, the lower beds against one another, so that in each set one header-side of the middle brick projected beyond the two others. The bricks were left in the cellar of the Laboratory

about 8 weeks. The adhesion experiments were made in the *Tinius Olsen* machine in pressing against the projecting header-side of the middle brick, as if one would drive back the brick to be flush with the two outer bricks.

The results of the experiments with the individual test-pieces agreed rather badly as is usually the case with adhesion experiments.

For mortar C the crushing strength was found to vary from 0,2 to 1,6 kg pr. sq. cm, the mean being 0,6 kg pr. sq. cm.

For mortar D the crushing strength was found to vary from 0,3 to 0,8 kg pr. sq. cm, the mean being 0,4 kg pr. sq. cm.

It may be inferred from this that if half of the calcic hydrate in a mortar with 5 per cent calcic hydrate is replaced by moler, the adhesion will at any rate be particularly diminished.

The Laboratory must be of opinion that according to what is before us it would prove profitable to replace a great deal of the calcic hydrate in lime mortar with moler and especially in humid places.

The moler has, indeed, come to be used in Frederiksholm's Limeworks for the producing of lime mortar, and the experiments of the Laboratory have been corroborated and the lime-moler mortar is very comfortable to work with.

h. Researches on Painting on Fresh, Surface-dry or Moist Cement-Plaster.

These researches were occasioned by the late city-architect in Copenhagen, Prof. *Fenger*, and executed for the magistracy of Copenhagen; they tended to find out how one could paint, especially paint in oil, on cement-plaster, as it is well known that oil-paint does not last in fresh cement-plaster, thus not where cement-plaster has newly been repaired, for instance on the walls in bathing establishments.

The Testing Laboratory considering the chemical attack derived from the plaster itself to be the essential in the majority of cases the experiments were made in such a way as to be sure that this influence came to be the only one working, i. e. the experiments were made as laboratory experiments.

As one of the by-influences that may occur during practical experiments may be named the pressure to which the water may be subject in moist masonry work. To imitate this

influence in a totally natural way will afford great difficulties at laboratory experiments, so great, that the Laboratory did not think itself able to overcome them without the experiments becoming too expensive.

In the Report X treating of the experiments an account is first rendered why fresh cement-plaster attacks oil-paint, so that 1 and 2 years ought generally to pass before the plaster is painted in oil, and then the methods are enumerated by which the named injurious influence can be counteracted. Finally the materials are treated of which have been used for the experiments, and how the latter were executed both in fresh surface-dry cement-plaster, and in fresh, moist cement-plaster.

As result of the experiments shall be named here that among the half score of materials tested the so-called *Fluociment*, invented by *Kessler*, was found to be the best for painting on fresh cement-plaster when surface-dry for which was, however, required an age of no more than a few weeks, while the so-called *Kautschukbutter* from *Chemische Fabrik Busse*, Hannover—Linden, was found to be best for fresh, moist cement-plaster and for the rest also very good in fresh surface-dry cement-plaster. In the treatise are finally mentioned some other materials who are in the market for the same use, but were not embodied in the series of experiments.

The experiments treated of under f occasioned the Laboratory to paint on plaster with cement and lime colours, for instance, to paint with a compound of cement and colour and render the paint washable in treating it with fluuate. On this occasion Miss *Klingberg*, at that time assistant of the Laboratory, tried to replace fluuate by a diluted dissolution of oxalic acid or a concentrated dissolution of oxalate of ammonia, as, for instance, ultramarine coloured plaster cannot stand oxalic acid, but very well oxalate of ammonia, and she employed these materials not only for painting on cement but also for painting on lime to render the painting washable. More particular details on this occur at the end of Report VI of the Laboratory.

i. Researches on Linseed Oil and Rust-preventing materials.

These researches were made for the Church and School Department and published in Report XII. The first part treating of researches on linseed oil was the object of a discourse delivered

by Prof. N. G. Steenberg, under whose charge they had been executed, at the International Congress for applied chemistry in Berlin 1903 and occurs translated into German in the report of the proceedings of the Congress. The second part has the following 4 main sections: formation of rust on iron, protection of the iron against rust by coatings of various kinds, attacks of the iron in spite of its being painted and how this is to be conceived and: testing of the value of rust-preventing means. The latter section is divided into two parts, of which the former gives a summary of various reports on previous experiments, partly practical, partly laboratory experiments, while the latter part treats of the series of experiments made by the Danish States Testing Laboratory.

For the rust-preventing means these consist to a great extent in:

- 1) Determination of the consumption of colour,
- 2) — - the drying power,
- 3) Exposure to heating up to 150—160° Centigrade,
- 4) — - gaseous sulphuretted hydrogen,
- 5) — - gaseous sulphurous acid,
- 6) — - gaseous hydrochloric acid,
- 7) — - vapour at atmospheric pressure,
- 8) — - tensioned vapours,
- 9) — at the same time to air, carbonic acid and vapour,
- 10) — to boiling water,
- 11) — - accumulator acid (sulphuric acid sp. g. 1,15),
- 12) — - a 3 per cent dissolution of common salt
 feeded with air and carbonic acid,
- 13) Testing of resistance to wear,
- 14) Examinations of the colour-films themselves especially as
 regards their permeability for liquids,
 and besides these series of experiments made in the form
 of laboratory experiments, also the following
 practical series of experiments:
- 15) Exposure to smoke-containing air,
- 16) Suspension at a tar reservoir in the Eastern Gas-works of
 Copenhagen.

In the said report XII it is stated more particularly how the colours were painted on small pieces of iron-plates either covered with iron-scale, or after the latter had been removed by immersion in glycerine-sulphuric-acid bath with ensuing careful rinsing with water and polishing with fine emery-cloth.

The drying power was determined in determining the point of time when the colour laid on had attained constant weight, it being assumed, that this was a rather good measure for the relative drying power of the colours, while from a practical point of view this manner of proceeding could of course not say anything of their absolute drying power. The constant weight was reached after from 1 to 18 days and nights, Antiferugin being 18 days and nights in reaching this weight.

The exposure to heating to $150\text{--}160^\circ$ Centigrade took place in an oven during 2×6 hours, and after the heating various bending tests were made partly with totally sharp bending, partly around bars of different diameters, and for comparison the same bending tests were made with painted iron-plates which had not been heated, and it was noted down whether the layer of colour parted or not from the various bendings or mouldered.

As to the exposure to gaseous hydrochloric acid, the paint of white-lead and white enamel-colour on iron plates proved to be quite destroyed already after the lapse of 4 hours while the other colours were able to stand the influence of many hours, up to 20 hours, gone through by Antiferugin.

It would be too long to render an account of the results of the many various experiments here. It is only to be specially quoted that the series of experiments 13 on resistance to wear were made in letting sand whose grains had a fixed size fall from a fixed height on painted circular iron plates of a diameter of 10 cm. The experiments were made with the apparatus shown at p. 83 in fig. 29. A is a funnel suspended by the string b passing across the pulleys a and a_1 ; the funnel carries two horizontal arms c and c_1 at right angles to each other (the latter only visible as a point on the figure) and supplied with eyes through which the strings b and b_1 pass. Arms and strings shall prevent the funnel from swinging to and fro. The taphole of the funnel can be shut by means of the stopper d which can be pulled out easily and quickly by means of the string fastened there.

Perpendicularly below A is placed the apparatus B to intercept the sand falling from A. In B is a horizontal circular disc f supported on 3 props and of the same diameter as the painted plates employed. C is a reservoir for the collecting of the sand. The experiment was made in the following way: After the tap-hole had been shut with the stopper d, the funnel was filled with about

1½ kg sand and hoisted up to such a height, that the distance from the tap-hole to the plate f was about 2½ m. Then the painted iron plates were placed on the disc f, d was removed by a rash pull in the string, and the sand began to fall, finally being picked up in C after working upon the painted plates. — As the case might be, this proceeding could be repeated several times with the same plate.

For the experiment were employed 2 different sorts of sand, partly Berlin-Normal sand (Sand I), partly down sand where the grains were of such a size that it passed through a sieve with 400 meshes pr. sq. cm, but was retained by one with 900 meshes pr. sq. cm (Sand II). On a colour proving, namely, to be immediately worn through when employing the first named sort of sand the smaller size of grains was tried. On this base the colours were placed in 4 classes.

We shall only state here that to the first class, that one most capable of resistance, came to belong chiefly such protective coatings where linseed oil varnish had been used as a medium which is beyond all doubt due to the elasticity of the linseed oil varnish, thus the same fact which makes linoleum last so well against sandblast jets. The medium being fragile, the coating springs off more easily when hit by the jet of sand.

The report of the wear-experiments, dealt with here, and of which a summary is only given here, has for the rest been translated in extenso into German in »Baumaterialienkunde« 1905, p. 168. There it is also set forth that a jet of sand was presumably employed for the first time for wear experiments — especially on wood — in this country (see the research published in 1893, and mentioned above, by Mr. C. V. Meldahl, graduate in forestry and civil-engineer), and reasons are also established why sandblast is hardly adapted to wear-experiments with wood. For wear-experiments with protective coatings the sand-blast seems to be more appropriate as, for instance, the paint on stays for electric tramways is no doubt much worn off by drifting dust and sand.

As of Report XII only the short section on the wear-experiments has hitherto been translated into a foreign language this report has presumably, apart from this, remained unknown except in the Scandinavian countries where the Danish language is understood. From an Annual Report from the Testing Laboratory in Stockholm it appears, indeed, that this Laboratory has adopted

several of the tests for protective coatings which the Danish States Testing Laboratory has recommended.

k. Experiments concerning Means for the Preservation of Wood.

These experiments, made after the proposal of Mr. *Irminger*, Manager of the Eastern Gas-Works of Copenhagen, were also executed for the Church and School Department, and provisional reports have been given by the Testing Laboratory in Report XI and in the Annual Reports for 1907 and 1908 of the Danish States Testing Laboratory by Mr. *Irminger*, in the capacity of chairman of a committee that has designed them.

For the experiments were employed pieces of wood of common spruce, white spruce, pine and mountain-pine and oak, white spruce and mountain-pine, however, only either as fencing posts or in the form of laths as stands, on which were laid some pieces of spruce and pine horizontally above the earth. Besides, a very great number of experimental pieces were formed of common spruce, pine and oak in a quite fixed manner; then they were placed in the earth, either horizontally under the surface or with the upper plane (a marrow side) horizontal in the surface of the earth itself or vertical half buried in the earth; part of this material was left unprepared, while another and greater part was prepared in 82 different ways by painting, impregnating etc.

The whole of the experimental material lies now at a distance of 6 km from Copenhagen at the station of Husum, in a ground kindly delivered up by the 2^d Department of the Royal Engineers, and is seen at p. 85 in fig. 30, and the purpose is to examine by and by the influence made by the weather upon it. As yet but few results are before us, — see the Annual Reports of the Laboratory for 1907 and 1908 — but next autumn we intend to commence a close examination of the state of the material.

The Report XI of the Laboratory gives the further details of the way in which the wood was cut out of the trunks, how it has been taken care of which side of the wood was turning northward, how notes were made on resin holes, diameter-increment, richness in knots, etc.

Fig. 31 at page 87 shows the wood when piled for drying after being cut out.

Before being prepared some researches were made of the wood. Thus determinations of specific gravity and humidity were

undertaken and measures were adopted for determination of ash; a great deal of wood was also put aside for the determination of the bending strength, made in the Testing Laboratory after a few years.

To obtain a result in figures for how much the wood placed vertically putrefies in the ground-line, it is, namely, the purpose to break it and examine how much it has lost in strength: During the bending it is not broken by a strain working in the very middle where it must have suffered most, but at a distance of $\frac{1}{3}$ of the free length from one of the supports.

It is chiefly Mr. *C. J. H. Madsen*, chemist at the Eastern Gas-Works with whom the considerable work of the committee has rested in keeping the material in order, directing the preparing in the many ways etc.

As far as our knowledge goes this series of experiments is the greatest one of its kind, set on foot. The plan worked out and the money granted, it became known that several years before experiments had been commenced on a similar line, but less comprising, in Finland, and a series of experiments of much the same kind have been reported by Prof. *M. E. Henry* at Ecole nationale des Eaux et Forêts at Nancy in the place named below¹⁾.

As early as 1895 the Danish Forestry Association has, for the rest, commenced comparative experiments of the durability of Danish and Swedish common spruce in building 8 uniform sheds where the two sorts of wood are employed alternately. It seems to appear from the inspection made in 1907 that Danish spruce had a somewhat greater resisting power, but the experiments are still continued²⁾.

1. Experiments on Impregnation of Wood against Fire.

The Laboratory has in the course of time made some experiments to judge how various coating means protect wood from fire. They were executed in a small apparatus made for this purpose where the wood in form of a round stick was laid at different altitudes above a row of gas-lights, and then it was observed how many seconds it was before the first gases, produced by the dry-distillation, were set on fire, and then, when the wood really

¹⁾ »Le Genie Civil« of the 19th of Sept. 1908.

²⁾ Tidsskrift for Skovvæsen, Bd. XX, 1908.

took fire, but to fix the latter moment is not easy. We shall not here enter more particularly upon these tests of which nothing is hitherto published, but an account will be rendered for tests of resistance to fire made with impregnated and unimpregnated wood and executed for *Akts. Dansk Imprægneringskompagni* at Copenhagen; the further details of these occur in the Annual Report of the Laboratory for 1908.

The experiments tended to find out how long it took to burn through some wood-flakes joined by slit and tongue of a size of some square metres.

The rule followed during the experiments was this. In an experimental house, built for the same purpose, and of which fig. 32¹⁾ at page 89 shows both a vertical section a—b, and the experimental house seen from above, were placed the said wood-flakes in a sloping position, as it appears from the vertical section, so that the flame from 3 gas-burners lying below could lick up along the flakes. During the experiment the temperatures could be measured by means of *Le Chatelier's* electric pyrometer, the latter being placed across the two nearest burners through the lower observation-hole.

It was noted, both when the flake had been burnt through and whether the wood, on the gas having been turned down, went on burning or became extinct by itself.

Altogether 8 experiments were made. The main result was: 5 impregnated flakes were burnt through in respectively 18, 20, 20, 46 and 50 minutes, while 3 unimpregnated were burnt through in 4 and 14 minutes. The gas having been turned down the wood-flakes of the unimpregnated wood went on burning without becoming extinct, but among the 5 impregnated wood-flakes this was not the case for 3 wood-flakes for more than at most a few minutes, and for two only in a few places and presumably especially because being boards of Pitch Pine where these were very resinous.

The photographs above show an impregnated flake alongside with an unimpregnated one after being worked upon by the fire through a quarter of an hour, respectively at p. 90 in fig. 33

¹⁾ On the figure: »Observationshul« means peep-hole,
 »Aftræk« means outlet and
 »Gasbrænder« means gas-burner.
 »Snit a—b« means section on a—b.

seen from the side facing the fire and at p. 91 in fig. 34 from the side turned away from the fire.

During the experiments the temperature was found to be about 700° Centigrade for the impregnated flakes, and about 50° Centigrade higher for the unimpregnated, but the statement of temperature must be considered rather uncertain.

m. Testing of Linoleum and Jointless Floor-Coating Masses.

In Report III of the Laboratory informations are given not only of the testing of linoleum etc. but also of its manufacturing and employment. The part of the report treating of the testing has been translated into German in »Baumaterialienkunde« 1901, p. 12.

Here it is recorded that the wear-testing method commonly followed for bricks in a machine of *Bauschinger's* or a like construction is not adapted to linoleum.

On employing emery as wearing powder, it is namely possible by this method to come to such abnormal and wrong results as that linoleum holds its own better against wear than granite, which is due to the fact that something of the wearing powder can fix itself in the linoleum, so that the surface of the latter becomes coated with emery powder, but then it is not really the linoleum which is tested, but a material the surface of which consists chiefly of emery powder.

By the method of the Laboratory for the testing of linoleum and jointless floor-coating masses such as papyrolith and the like to wear a wooden block coated with sand-paper is drawn to and fro across the material under a certain, light pressure, and at each 500th double stroke the sand-paper is changed; the latter must, of course, be of a certain fixed fineness becoming else too much filled or choked up. As dealt with more closely in the report of the Laboratory, it is possible at a very small expense to transform a simple American cold-saw into a wear-testing machine for linoleum etc. For the tests the linoleum is mounted on a piece of plate-glass.

The imperfection of the method is willingly admitted and Geh. Regierungsrat, Prof. Dr. *Martens* has in »Baumaterialienkunde« 1901, Nr. 1 and 2, urged some objections against it, but the drawbacks may possibly be smaller than the advantages

as shown by the director of the Testing Laboratory in the same Review 1901, Nr. 11.

The Laboratory persists therefore in considering the test ap-

Tabel XI. Test of Resistance to Wear of Floor-Coating Material.

Loss of weight in per cent of the weight of the test piece referred to a thickness of 4 mm	Linoleum, number of sorts	Jointless floor coating masses, number of sorts
up to 0,10		3
from 0,11—0,20	10	1
- 0,21—0,30	30	3
- 0,31—0,40	24	1
- 0,41—0,50	6	3
- 0,51—0,60	9	2
- 0,61—0,70	2	1
- 0,71—0,80	1	4
- 0,81—0,90		
- 0,91—1,00		3
- 1,01—1,25		
- 1,26—1,50		1
- 1,51—1,75		2
- 1,76—2,00		
over 2,01		2
Number of Sorts, altogether . .	82	26

propriate. If the linoleum is too fresh and therefore too soft, the test will show bad results, and, the medium being fragile and bad, hard linoleum will also yield bad results. The method has, indeed, been adopted in some other places and is, for instance, followed at the Testing Laboratory of Gothenburg¹⁾ and at the Hungarian State-Railways.

In the Table XI above is given an account of all the results come to by the Laboratory until the 1st of January 1909.

¹⁾ In Gothenburg the method has been found more appropriate than the application of »Bauschinger's« machine, see »Baumaterialienkunde« 1904, Nr. 23.

n. Testing of Caoutchouc Articles.

The Laboratory has tested several of this kind of articles, for instance, caoutchouc hoses, caoutchouc packing rings and rubber soles.

For hoses the caoutchouc has especially been chemically examined, but tests of resistance to internal pressure have also been made.

As to caoutchouc packing rings and other packing rings the Laboratory has for one thing tested them in clamping different sorts between flanges in an apparatus, to which saturated or overheated steam could be led during a longer period, and then researching whether they were tight during the experiment and how their state was when taken out of the apparatus. In Report II of the Laboratory details are given as to a variation of this method.

Such a method gives, of course, no definite particulars as to how the packings will hold out when used, but only some information. Fig. 35 at p. 95 shows to the left 4 different new packing rings, and to the right they are seen after going through the same treatment in an apparatus as that recorded in Report II, and it is to be seen how extremely unlike different packing rings stand the same treatment. This picture has not been published before.

For the testing of resistance to wear of rubber soles the Laboratory — as recorded in »Baumaterialienkunde« 1905, Nr. 11 — 12 — employed a similar method as for the testing of linoleum. As only smaller pieces of rubber soles can be obtained, these can not without further ceremony be fastened on the plate-glass instead of the linoleum, not affording sufficient guiding for the wooden block, covered with sand-paper and wandering to and fro; the latter will therefore begin to swing when moving, and the method has been modified so far that a piece of Carborundum-paper is laid round the plate-glass, while under the block 2 rectangular test-pieces are fastened at the ends, namely 1 taken out of each rubber sole. Not to spoil the wooden block, the test-pieces are not pasted directly under it, but on the underside of the block there is screwed a couple of aluminium plates and to these the test-pieces are pasted by means of a solution of caoutchouc. The aluminium plates project a little beyond the test-pieces so that outside these

there is room for the screws by which the aluminium plates are fastened to the wooden block. As the aluminium plates can be screwed on and off the wooden block, while the test-pieces are pasted to them, it is obtained that before and after the experiment the aluminium plates alone with the test-pieces can be weighed without weighing the whole block, consequently a finer balance can be employed. The block, when using rough sand-paper, wandering much more unsteady than when the linoleum was tested, owing to the elasticity of the test-pieces, so that the block wandered in small jumps, and the wear on fine sand-paper wood become slight, Carborundum-paper from the Carborundum Co., Niagara Falls, N. Y., Nr. 70 grain is employed.

Further, the Carborundum-paper is changed only for every thousandth stroke, and the wooden block is turned for every two-hundredth stroke. The latter is done because a sheet of Carborundum-paper is employed round each half-part of the plate-glass. Another deviation from the experiments with linoleum has finally been necessary namely to reduce the distance which the block has to wander, the velocity of rotation of the machine being continually the same, by which a slower and more steady movement of the block has been obtained. Thus it is possible now to get the rubber soles worn plane, while the unsteady movement wears off the surfaces to be extremely convex.

The size of the test pieces is $7,5 \times 5,0$ cm. The block and the load is the same as that employed during the experiments with linoleum and explained in the treatise mentioned above. The size of the aluminium plates is $7,5 \times 9,5 \times 0,4$ cm. The weight of the block together with the aluminium plates and the load is 3,61 kg.

In the Table XII below are seen results from the experiments of the Laboratory up to 1st of August 1909; r and l designate that a test-piece is derived respectively from a right or left sole, r_1 and r_2 that the two test-pieces are derived from the same right sole.

Instead of testing in the named way a test-piece of each sole in a pair of rubbers, each of the test-pieces can, of course, be made to derive from a sole in two different sorts of rubbers.

From the loss of weight, the weight of the test-piece and the specific gravity of the stuff the volume worn off is, of course, to be calculated.

Tabel XII. Tests of Resistance to Wear of Rubber Soles.

Mark of the rubbers	Mark of the test-piece	Number of double strokes	Area of the test piece in sq. cm	Loss of weight of the test-piece in g	Loss of weight in g pr. sq. cm	Notes
A	1 r_1	0—2000	36,4	1,50	0,041	The furrows in the sole were not worn off totally by the 2000 strokes.
	1 r_2	0—2000	38,0	1,51	0,040	
	1 r_1	2—4000	36,4	0,82	0,023	The furrows had not yet been quite worn off.
	1 r_2	2—4000	38,0	0,91	0,024	
B	2 r_1	0—2000	40,5	2,45	0,060	The furrows in the sole were worn off after the first 2000 strokes.
	2 r_2	0—2000	39,0	2,26	0,058	
	2 r_1	2—4000	40,5	2,47	0,061	
	2 r_2	2—4000	39,0	2,25	0,058	
C	3 r	0—2000	37,5	1,15	0,031	The furrows in the sole were not worn quite off by the 2000 strokes.
	3 l	0—2000	37,5	0,98	0,026	
	3 r	2—4000	37,5	0,73	0,019	The furrows in the sole were not quite worn off.
	3 l	2—4000	37,5	0,72	0,019	
D	4 r	0—2000	37,5	0,90	0,024	The furrows in the sole were not quite worn off by the 2000 strokes.
	4 l	0—2000	37,5	0,85	0,023	
	4 r	2—4000	37,5	0,75	0,020	The furrows in the sole were not yet quite worn off.
	4 l	2—4000	37,5	0,64	0,017	
E	5 r	0—2000	37,5	1,39	0,037	The furrows in the sole were worn off after the first 2000 strokes.
	5 l	0—2000	37,5	2,02	0,054	
	5 r	2—4000	37,5	1,91	0,051	
	5 l	2—4000	37,5	2,20	0,059	
F	6 r	0—2000	37,5	2,15	0,057	The furrows in the sole were worn off after the first 2000 strokes.
	6 l	0—2000	37,5	1,25	0,033	
	6 r	2—4000	37,5	2,38	0,063	
	6 l	2—4000	37,5	3,33	0,089	
G	7 r	0—2000	37,5	2,44	0,065	The furrows in the sole were worn off after the first 2000 strokes.
	7 l	0—2000	37,5	2,48	0,066	
	7 r	2—4000	37,5	1,74	0,046	
	7 l	2—4000	37,5	1,73	0,046	
H	8 r	0—2000	37,5	1,23	0,033	The furrows in the sole were not worn off by the first 2000 strokes.
	8 l	0—2000	37,5	1,08	0,029	
	8 r	2—4000	37,5	0,75	0,020	The furrows in the sole had not yet been quite worn off.
	8 l	2—4000	37,5	0,61	0,016	
	9 r	0—2000	56,2	1,77	0,031	
	9 l	0—2000	56,2	1,80	0,032	
	9 r	2—4000	56,2	1,89	0,034	
	9 l	2—4000	56,2	2,10	0,037	
	10 r	0—2000	55,5	1,72	0,031	
	10 l	0—2000	55,5	1,62	0,029	
	10 r	2—4000	55,5	0,55	0,010	
	10 l	2—4000	55,5	0,60	0,011	

o. Various Researches.

In the course of time a great many examinations have, of course, been made at the Danish States Testing Laboratory beyond those stated above. Some of these are to be named here.

Thus the common examinations of paper, yarn and stuffs have been made. The Laboratory being badly equipped for the testing of yarn and stuffs, we have been obliged to help ourselves in the best possible way. Thus the apparatus shown in p. 78 in fig. 28 for adhesion experiments has been employed for testing the strength of string for mowers, one end of the yarn being fastened to the dynamometer M, while the other end were wound round the axle A.

A single time the Laboratory has tried to examine the resistance to wear of cloth in determining which sort of cloth among several forwarded could be assumed to give off the least of fluff when worn, as the cloth was to be employed by ladies serving fine apparatus which were disturbed on fluffs flying into them. From the different sorts of cloth uniform square pieces were cut off, the one narrow edge of which was fastened along generators on a drum at the same distance from one another. Near the drum was placed a sloping board coated with sand-paper, so that on the drum rotating the floating pieces of cloth were dragged in the same way down the surface of the sand-paper and thus worn. Afterwards the appearance of the sorts was judged of. Although being far from good the tests gave some information nevertheless, and were, indeed, very simple and cheap.

For the examination of isolating materials for steam-pipes the Laboratory has employed an installation, principally the same as that found in the Testing Laboratory in Gothenburg and described in the place named below¹⁾.

To examine the resistance of incandescent mantles to shakings the Laboratory had an apparatus made as shown at p. 99 in fig. 36 by means of a rather simple addition to a *Böhme's* hammer-apparatus of older construction¹⁾.

The lever-prop V is laid with a knife edge O dividing it in the proportion 1 : 2 on a support. The support is anchored by means of some of the ties of the hammer-aparatus, as it

¹⁾ Svensk tekn. Tidskrift 1901.

²⁾ Annual Report of the Laboratory 1903.

reaches in underneath the left end of the foundation - slab of the hammer-apparatus, and with its horn A it supports V at a distance of 16 cm from the left end of V. The usual hammer is replaced by one the falling weight of which is only 1 kg. The breadth of the lever-prop, at right angles with the plan of the paper, is 15 cm, its weight being 51,5 kg. B is the burner on which the incandescent mantle is fastened, and the number of strokes required up to the time when the net is torn to pieces and tumbles down, is counted. To be able to shake the incandescent mantle in vertical direction instead of horizontally there is also a hole in the lever-prop in the place designated with a dotted line for the application of a gas-burner. The test is made when the net is cold. The figure also shows how *Böhme's* hammer is adapted to driving with belt-pulling the belt being placed round the pulley R. On adding the lever U and the weight P it is obtained that the belt springs off after 150 strokes.

To examine the resistance of china-plates to blows the Laboratory has employed a variation of the apparatus shown in p. 25 in fig. 8. The plate is clasped at an angle of 45° and hit by strokes from a one-armed lever at the top of and near the end of which an iron hoop keeps the lever in a sloping position on the iron hanging at the electro-magnet E in fig. 8. Each plate is tested in several places of the circumference. Any special experience has not yet been obtained with this apparatus.

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